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RECEIVED 11 August 2025

ACCEPTED 17 October 2025

PUBLISHED 31 October 2025

CITATION

Wang T and Sun Y (2025) From marine pollutant characterization to regional practice: implications of ITLOS Advisory Opinion No. 31 for the maritime sectors and Hainan FTP's governance adaptation. *Front. Mar. Sci.* 12:1683617. doi: 10.3389/fmars.2025.1683617

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From marine pollutant characterization to regional practice: implications of ITLOS Advisory Opinion No. 31 for the maritime sectors and Hainan FTP's governance adaptation

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The International Tribunal for the Law of the Sea (ITLOS) issued Advisory Opinion No.31 regarding the characterization of GHGs and obligations of the State Parties to UNCLOS. This study combines legal and policy research methods to forecast its implications on the maritime sectors and provide response suggestions. The legal analysis part employs a doctrinal legal analysis to examine obligations outlined in the ITLOS Opinion and relevant international instruments, and a socio-legal analysis to examine the impacts of the ITLOS Opinion. The policy research part adopts a qualitative approach to gather and review policy documents related to China's involvement in "Green Shipping Corridor" initiatives and port policies, and conducts a case study analysis to select Hainan Province as a representative example for development suggestions. Our study showed that the ITLOS opinion No. 31 plays a catalytic role in global shipping decarbonization and may trigger a series of ripple effects on the global maritime sector. As China's only Free Trade Port (FTP) and the special province connecting East Asian and Southeast Asian countries, Hainan Province is suggested to monitor advancements in global energy technology and track orders for "green vessels" to forecast future demand for green shipping fuels accurately; establish "green shipping corridors" through regional cooperation mechanisms among the South China Sea region; and apply preferential national policies for pilot programs in green shipping energy supply by use of the FTP status.

KEYWORDS

shipping decarbonization, ITLOS Advisory Opinion No. 31, port cooperation in the South China Sea region, green shipping corridor, climate change and the law of the sea

1 Introduction

In December 2022, the Commission of Small Island States (hereinafter referred to as “COSIS”) submitted a request to the International Tribunal for the Law of the Sea (hereinafter “ITLOS”) for an advisory opinion. This request sought clarification on the specific obligations of States Parties to the UNCLOS regarding their responsibilities to respond to climate change and to protect and preserve the marine environment affected by climate change. On May 22, 2024, ITLOS issued Advisory Opinion No. 31 on Climate Change and Pollution of the Marine Environment (hereinafter “the Opinion”) (ITLOS, 2024), which places increased pressure on States Parties to reduce carbon emissions.

Since ITLOS issued the Opinion, 34 States Parties to the UNCLOS, including China, India, Brazil, the United Kingdom, and Australia, as well as 9 international organizations such as the United Nations and the African Union, have submitted written statements. During the oral proceedings, 33 UNCLOS States Parties, including China, the UK, and India, along with the African Union, the International Union for Conservation of Nature (IUCN), and the Pacific Community, presented oral statements (Li, 2025). The political and legal issues raised by this case have sparked extensive discussion among governments, non-governmental organizations (NGOs), and academics.

Scholars adopting interdisciplinary political and legal perspectives have systematically analyzed the motivations behind COSIS in seeking an advisory opinion (Kim and Kim, 2025; Lando, 2023). They argue that its core objectives were to enhance negotiating leverage, pressure major emitting states, transform voluntary commitments under Nationally Determined Contributions (NDCs) into binding obligations through legal clarification, and establish a legal basis for the “loss and damage” funding mechanism (Kim and Kim, 2025). ITLOS was chosen primarily due to the relatively lower threshold of its advisory procedure and the Tribunal’s perceived tendency towards a broad interpretation of matters “related to the purposes of UNCLOS”, thereby increasing the likelihood of the request being accepted and linking climate obligations to human rights and intergenerational equity aimed to broaden impact and catalyze political change (Lando, 2023).

The question of ITLOS’s advisory jurisdiction emerged as the primary scholarly controversy. While some scholars acknowledged ITLOS’s jurisdiction over the COSIS request (Tigre and Rocha, 2023), the prevailing view contends that neither UNCLOS nor the ITLOS Statute explicitly confers general advisory jurisdiction on the full Tribunal (Gong, 2023; Guo and Xiao, 2025). Critics argue that ITLOS’s self-conferred advisory jurisdiction lacks an explicit treaty basis and risks judicial overreach without state consent (Que, 2024; Shen, 2024; Zhu, 2024). Concerns were raised that using the advisory opinion to circumvent the principle of consent could damage ITLOS’s judicial credibility (Lando, 2023).

Regarding the core legal question addressed in the Opinion—whether greenhouse gases (GHGs) constitute “marine pollution”—some scholars support the Tribunal’s finding that GHG emissions meet the definition of “pollution” under Part XII of UNCLOS

(Barnes, 2022; Freestone et al., 2022; Klerk, 2025; Lando, 2023). They cite supporting scientific evidence of “harmful effects” such as ocean acidification and sea-level rise (Baars, 2023). However, other scholars challenge this interpretation as lacking a sufficient scientific basis (He, 2024; Wang and Pang, 2024). They contend that while the Tribunal relied on reports of the Intergovernmental Panel on Climate Change (IPCC) to establish the “harmfulness” of GHGs, it failed to analyze specific damage thresholds. Furthermore, the Opinion disregarded the specialized nature of the United Nations Framework Convention on Climate Change (UNFCCC), potentially resulting in judicial ultra vires, blurring the lines between legal interpretation and policy-making (He, 2024; Wang and Pang, 2024), and conflating fact-finding with legal analysis (Thin, 2025).

Beyond defining pollution, ITLOS interpreted the obligations of States Parties provided by UNCLOS concerning GHG emission reductions. Scholars note that such interpretations can help clarify legal duties, prompting states to revise domestic policies and providing grounds for climate litigation (Baars, 2023). Building on ITLOS’s reasoning, scholars have further analyzed the obligations mentioned in the Opinion, including due diligence, mitigation, monitoring and assessment, cooperation, and enforcement obligations (Baars, 2023; Zeng and Wang, 2025). Notably, some scholars point out that the Opinion imposing stringent “due diligence” standards, as well as new obligations of restoring and improving the marine environment and financial assistance, extend beyond the explicit provisions of UNCLOS Part XII (Gong, 2023; Li, 2025; Zhang, 2025). However, the discussion on “due diligence” in the Opinion can also apply to Japan’s Fukushima radioactive nuclear wastewater discharge incident (Chang, 2025). Besides, the interpretation of the Opinion potentially disregards the principle of “Common But Differentiated Responsibilities” (CBDR) (Qian et al., 2024).

Summarizing the previous academic research, most of the research focuses on analyzing the Opinion from the perspectives of jurisprudence and legal interpretation. Where the impacts of the Opinion are considered, the focus is primarily on international law, domestic legislation, and international relations. The discussion about the influence on specific industries, especially the shipping and port industry, which are directly impacted by the Opinion, is not fully and well discussed, and the discussion on the response plan of the port industry is even less. Under the Carbon Peak and Carbon Neutrality framework, the global shipping industry is undergoing a low-carbon transformation. In the context of the Opinion, the classification of GHGs as marine pollutants establishes legal ground for regulating shipping emissions, and the Opinion incorporates the International Maritime Organization (IMO) standards within the scope of “necessary measures”, which will catalyze the process of international shipping decarbonization. As a downstream industry providing infrastructure services to the shipping sector, the port industry faces direct challenges and impacts from this Opinion, while also being presented with new development opportunities. Therefore, research on the implications of the Opinion on the shipping and port sectors and corresponding adaptation strategies is imperative.

This study provides a detailed interpretation of obligations related to shipping decarbonization that ITLOS deems incumbent upon States Parties to UNCLOS, as outlined in the Opinion. Based on the interpretation, it forecasts the implications of this Opinion on future development of the shipping and port industries worldwide. Additionally, it chooses ports in Hainan Province — China's southernmost maritime province, the only free trade port (FTP), and a strategic island bridging the Pacific and Indian Oceans, as an example for analysis. By leveraging Hainan's geographic advantages, tax incentives, and abundant green resource reserves, the study proposes targeted recommendations for advancing its port industry in alignment with global decarbonization trends.

This study combines legal and policy research, adopting a mixed-methods approach to ensure a comprehensive analysis. The legal analysis part employs two primary analysis methods. First, a doctrinal legal analysis was conducted. This involved a systematic legal interpretation and textual examination of the ITLOS Advisory Opinion No. 31, the relevant provisions of UNCLOS, and other relevant international legal instruments. Subsequently, the research employed a socio-legal analysis to critically examine the practical impact and ripple effects of the ITLOS Opinion, particularly its influence on the development of global maritime sectors, and its subsequent incorporation into national and regional legislative and enforcement frameworks. The policy research part adopts a qualitative approach. It involves the systematic gathering and review of policy documents about China's involvement in "Green Shipping Corridor" initiatives, with a specific focus on port policies. Additionally, a case study analysis is conducted, selecting the Hainan FTP as a representative example to develop actionable, context-specific policy and governance recommendations for the Hainan FTP.

2 Obligations on carbon emission reductions from ships under the ITLOS Advisory Opinion No.31

ITLOS emphasizes the following obligations on carbon emission reductions from ships in the Opinion:

1. Emissions of greenhouse gases from ships are anthropogenic GHG emissions and constitute "pollution of the marine environment" within the meaning of Article 1, paragraph 1 (d), of the UNCLOS [para. 441(a)(e) of the Opinion].
2. Obligation of States to take all necessary measures to prevent, reduce, and control marine pollution from greenhouse gas emissions from all sources [para. 441(b) of the Opinion].
3. Under Article 211 of the Convention, States Parties are required to adopt laws and regulations aimed at preventing, reducing, and controlling marine pollution resulting from greenhouse gas emissions from ships flying their flag or registered under their national registry. These laws and regulations must be at least as effective as the

internationally accepted regulations and standards established by competent international organizations or through general diplomatic conferences [para. 441(g) of the Opinion].

4. Under Article 217 of the UNCLOS, States Parties are obligated to ensure that ships flying their flag or registered under their national registry comply with applicable international regulations and standards established by competent international organizations or general diplomatic conferences. Additionally, they must adhere to their national laws and regulations concerning the prevention, reduction, and control of marine pollution from greenhouse gas emissions originating from ships. To ensure compliance, States Parties shall adopt and implement appropriate laws and regulations, as well as take the necessary measures to ensure their effective implementation [para. 441(i) of the Opinion].

Through the above content, the Opinion clarifies that UNCLOS States parties bear explicit obligations regarding carbon emission reductions from ships, including the obligation of due diligence, legislative obligation, and enforcement obligation. These obligations constitute state obligations, and non-compliance may trigger potential state responsibility. The exact contents of these obligations will be detailed below.

2.1 Obligation of due diligence

By referencing Article 194 of UNCLOS, the Opinion points out that States Parties should bear the obligation of due diligence in the prevention and control of GHG emissions, especially GHG emissions from ships. This obligation requires States to take all necessary measures to prevent, reduce, and control marine pollution caused by GHG emissions, to coordinate their policies in this area, and to diligently work towards these goals. The legislative intent behind this obligation is to empower States Parties to make their best efforts to prevent, reduce, and control pollution of the marine environment. ITLOS characterizes this obligation as a conduct obligation rather than a result obligation, which means States are not mandated to achieve the desired outcome by this obligation, but are required to take appropriate measures to work towards that objective instead (para. 233 of the Opinion). In determining whether a State Party fully performed its obligation of due diligence, ITLOS listed the following standards:

First, the obligation requires States Parties to establish a national mechanism to address marine pollution. This includes enacting legislation, implementing administrative procedures, and enforcing laws to regulate the activities of both public and private entities. Additionally, it is essential to ensure the effective functioning of this mechanism by closely monitoring whether administrative controls adequately regulate the behavior of these actors (para. 235 of the Opinion). In Articles 211 and 217, the UNCLOS reaffirms the legislative and enforcement obligations of States Parties regarding the reduction of carbon emissions from

ships, which will be discussed in detail below and will not be reiterated here.

Furthermore, the standard of “due diligence” should be decided objectively by scientific and technical information, relevant international regulations and standards, and the harm and urgency of the risk. The higher the risk, the more stringent the “due diligence” requirements imposed on the State Parties (para. 243 of the Opinion).

Besides, the standard of “due diligence” varies based on the means available to States Parties and their capabilities (para. 240 of the Opinion). This indicates that developed and developing countries may apply different standards to assess the fulfillment of the obligation of due diligence.

Ultimately, the obligation of due diligence entails implementing a precautionary approach to risk management. To prevent, reduce, and control marine pollution resulting from anthropogenic greenhouse gas emissions, States Parties are obligated to adopt the precautionary approach concerning the risk of pollution from activities within their jurisdiction or control. They must also take measures to mitigate this risk, even if the available scientific evidence is insufficient to establish the certainty and severity of the potential harm. Failure to do so will result in a breach of their obligation of due diligence (para. 242 of the Opinion).

2.2 Legislative obligation

By invoking Article 211 of UNCLOS, ITLOS affirmed that States Parties must adopt domestic laws and regulations to prevent, reduce, and control carbon emissions from vessels flying their flag or of their registry. The minimum threshold for such legislation is alignment with “generally accepted international rules and standards adopted by the competent international organization or general diplomatic conference.”

In terms of “generally accepted international rules and standards”, UNCLOS does not have a clear explanation. In the Opinion, ITLOS recognizes that such regulations and standards are those contained in international legal instruments developed through competent international organizations or general diplomatic conferences and accepted by a sufficient number of States. ITLOS further points out that the “competent international organization” for carbon emissions reduction from ships is the IMO (para. 43 of the Opinion). It is noteworthy that the IMO has developed commitments that are aligned with the Paris Agreement (Borg, 2023), which includes its strategy to reduce GHG emissions from the shipping industry. However, due to the limitations inherent in the IMO’s mandate, its efforts remain sector-specific and do not comprehensively integrate the broader role of the oceans in global climate change. As a result, compared with IMO’s achievements in the field of environmental pollution, there are significant gaps in fully leveraging the marine environment’s potential in mitigation and adaptation strategies (Li and Xu, 2020).

The Opinion points out that international regulations and standards relating to carbon emission reductions from ships refer

to the amendments to Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) adopted by IMO in 2011 and 2021 (paras. 280, 291 of the Opinion). However, it is essential to note that during the 83rd session of the IMO Marine Environment Protection Committee (MEPC), which took place from 7 to 11 April 2025, a new amendment to Annex VI of the MARPOL Convention was approved by vote. The latest amendment will be presented to the MEPC for final consideration and adoption in October 2025, with an anticipated entry into force in 2027. At that time, the amendment will also become “generally accepted international regulations and standards”, and UNCLOS Parties shall revise or enact their national legislation following the latest amendment.

2.3 Enforcement obligation

By directly invoking the provisions of Article 217 of UNCLOS, the Opinion interprets that States Parties to UNCLOS shall adopt all necessary legislative, administrative, and judicial measures to ensure that vessels flying their flag or of their registry comply with applicable international rules and standards and their domestic laws, as well as regulations related to ship decarbonization.

Between “generally accepted international rules and standards” as outlined in Article 211 and “applicable international rules and standards” under Article 217, there is no clear interpretation of the distinction between the two terms in UNCLOS. In the absence of a definitive interpretation of “applicable” under UNCLOS, and lacking a record of the negotiations that would clarify the origin or intent of the term, the American Branch of the International Law Association (ILA) has explained that the term “applicable” in Article 217 could be equated with “generally accepted.” However, it also cautioned that such an interpretation might lead to unreasonable outcomes when the term “marine pollution” is applied in other contexts. In contrast, in the Opinion, ITLOS adopts a literal interpretation, construing the term “applicable international rules and standards” as referring to those rules and standards that are legally binding on the relevant states, and further specifying that such rules and standards must also be those adopted through competent international organizations or general diplomatic conferences (para. 289 of the Opinion). ITLOS likely introduced this distinction because Article 217 pertains to states’ enforcement obligations, requiring states to implement only those international rules or standards to which they have acceded or that are otherwise legally binding upon them through other mechanisms. While the term “applicable” in its literal sense suggests a narrower scope of rules and standards than “generally accepted”, Article 211 already mandates that states adopt domestic legislation aligned with generally accepted international rules and standards. Since states are obligated to enforce their domestic laws, the practical outcome is that even international rules and standards not legally binding on a state may ultimately be implemented through their incorporation into domestic legislation.

3 The legal effect of the ITLOS Advisory Opinion No.31 and its catalytic role in shipping decarbonization

3.1 The opinion is not legally binding

The Opinion issued by ITLOS lacks binding legal force, due to jurisdictional limitations concerning ITLOS and the inherent nature of advisory opinions.

3.1.1 The full Tribunal's advisory competence lacks a solid legal foundation

This view is shared by China, Australia, India, Brazil, etc (Federative Republic of Brazil, 2023; Ministry of foreign Affairs of the P.R.C., 2023; the Republic of India, 2023). Advisory jurisdiction serves as the prerequisite for an international judicial body to issue advisory opinions, and without it, the body lacks the authority to entertain requests for such opinions.

Articles 159 and 191 of the UNCLOS explicitly grant advisory power only to the Seabed Disputes Chamber of ITLOS, not to the full Tribunal (Gong, 2023; Guo and Xiao, 2025). Although ITLOS first affirmed its advisory competence in the 2015 Advisory Opinion concerning the Sub-Regional Fisheries Commission (hereinafter “Advisory Opinion No. 21”) and reiterated this stance in Advisory Opinion No. 31, its reasoning rests on shaky grounds. ITLOS relied primarily on Article 21 of the Statute of the Tribunal (hereinafter “the Statute”) and article 138 of the Rules of the Tribunal (hereinafter “the Rules”) (para. 4 of the Opinion).

Article 21 of the Statute states that “[t]he jurisdiction of the Tribunal comprises all disputes and all applications submitted to it in accordance with this Convention and all matters specifically provided for in any other agreement which confers jurisdiction on the Tribunal.” ITLOS interprets the term “all matters” as “includ[ing] advisory opinions”, thereby created for itself an advisory competence in general and jurisdiction over the specific request in that proceeding (paras. 84-87 of the Opinion). However, as clarified in the written statement submitted by the Chinese government, a comparison with the French text of the Statute indicates that “all matters” refers only to the “disputes and applications” mentioned in the first part of the article, and does not include advisory opinions. Furthermore, China’s statement also employed historical interpretation, referencing records from the Third United Nations Conference on the Law of the Sea to demonstrate that a proposal to grant advisory power to the full Tribunal was rejected during negotiations. This indicates that ITLOS’s interpretation is lacking consensus among states and exceeds the original intent of the drafters. Additionally, ITLOS’s view that “other agreements” may confer advisory jurisdiction according to Article 21 allows states to circumvent the Statute through bilateral or multilateral treaties—an approach that violates

the fundamental principle of state consent (Li et al., 2023). This expansive interpretation was already contested during Advisory Opinion No. 21, where Australia argued that ITLOS could not base advisory jurisdiction on treaties independent of UNCLOS, since UNCLOS itself grants no such authority (Australia Government, 2013).

ITLOS also cited Article 138 of the Rules, which permits the full Tribunal to give an advisory opinion if an international agreement related to the purposes of UNCLOS expressly provides for such a request (para.93 of the Opinion). It is the only provision explicitly addressing the full Tribunal’s advisory jurisdiction. However, as a procedural rule adopted by ITLOS itself, Article 138 cannot substantively confer jurisdiction that ITLOS otherwise lacks (Shen, 2024). Indeed, in the Advisory Opinion No. 21, ITLOS itself stated that Article 138 is “a procedural provision [that] cannot serve as a basis for the advisory jurisdiction of the Tribunal” (ITLOS, 2015). Moreover, since ITLOS was established by UNCLOS, the existence of its jurisdiction must ultimately be determined by reference to UNCLOS. The Tribunal’s “self-authorization” based on its own Rules exceeds the powers conferred by UNCLOS and violates the principle of state consent (Lando, 2023; Li et al., 2023; Thin, 2025; Yao and Tong, 2025), and potentially undermining the original intent of UNCLOS (Zhang, 2025).

In both Advisory Opinions No. 21 and No. 31, ITLOS’s jurisdictional reasoning appears tenuous and has attracted significant criticism from judges and scholars. Professor Yoshifumi Tanaka questioned the legal basis for the full Tribunal’s advisory jurisdiction, arguing that it deviates from the requirements of its Statute (Tanaka, 2023a). Judge Cot noted that the interpretation risks misinterpretation as it contravenes the 1969 Vienna Convention on the Law of Treaties (Cot, 2015). ITLOS has embarked on a path of expanding its powers—a trend evident in Advisory Opinion No. 21 and further extended in the current Opinion No. 31 proceedings, raising concerns about potential abuse (Li et al., 2023).

3.1.2 The advisory opinion is not official source of international law

According to Article 38 of the Statute of the International Court of Justice (ICJ), sources of international law with binding force only include “a. international conventions ... recognized by the contesting states; b. international custom, as evidence of a general practice accepted as law; c. the general principles of law recognized by civilized nations.” Advisory opinions, however, fall under Article 38(1)(d), which refers to “judicial decisions” as “subsidiary means for the determination of rules of law.” They belong to the material sources of international law, which provide evidence of the existence of the rules. (Tanaka, 2023b) As explained by the International Law Commission, advisory opinions serve to clarify, interpret, and ascertain rules of international law but do not impose direct, mandatory legal obligations on states (Report of the International Law Commission, p. 31).

3.2 The advisory opinion can produce indirect legal effects

Although not legally binding, as one of the material sources of the international law, the ITLOS Advisory Opinion can still produce indirect legal effects, due to its functions of identifying the existence of the rules in international law, contributing to further consolidating the normative status of international law, clarifying the meaning and scope of relevant rules, and promoting the development of international law (Tanaka, 2023b).

Drawing from past international judicial practice, advisory opinions have often been regarded as authoritative statements on general international law (Gao et al., 2012). These opinions play a considerable role in clarifying, interpreting, confirming, and developing international law (Zeng, 1998). The International Law Commission has observed that, based on existing international jurisprudence, the “rules” of international law as evidenced by “judicial decisions” encompass all potential rules and principles under the sources of international law (General Assembly of UN, 2024). These “rules” have the status of legally binding rules after being proved, and often possess general applicability and inevitably produce legal effects for other states—a phenomenon described as “normative externality” (Mayer, 2023). When an advisory opinion serves to prove, interpret, or ascertain rules of international law, it may be invoked as a basis for decision by international courts. In practice, the ICJ frequently references its own prior decisions and increasingly cites rulings from other international courts and tribunals (General Assembly of UN, 2024). Consequently, the content of an ITLOS advisory opinion may be indirectly enforced and produce legal effects through recognition and citation by other judicial bodies.

Besides that, advisory opinions issued by ITLOS or other international courts may guide the conduct of international subjects in global affairs, creating a sense of moral obligation for states. In fact, small island states’ strategy of seeking advisory opinions from multiple international judicial bodies can be seen as an attempt to exert moral pressure on other nations (Kim and Kim, 2025).

In conclusion, while the ITLOS Advisory Opinion lacks direct legally binding force, its practical impact demonstrates a *de facto* normative effect on state conduct.

3.3 Catalytic role of the opinion in shipping decarbonization

In interpreting UNCLOS obligations, ITLOS incorporated the Paris Agreement as an external rule applicable to UNCLOS States Parties. Some scholars emphasize the autonomy of UNCLOS obligations, advocating for their coordinated interpretation with climate agreements (Klerk, 2025; Voigt, 2023). Conversely, others criticize ITLOS’ expansive interpretive approach in applying external rules to UNCLOS. They argue there is insufficient basis

for harmonizing climate change and ocean governance regimes (Li, 2025). Critics also describe the use of external rules as overly “selective,” lacking transparency (Longo, 2025; Thin, 2025). Notwithstanding considerable controversy, the interpretation of ITLOS has in fact linked climate change to UNCLOS and thereby significantly accelerated the global shipping decarbonization process.

3.3.1 IMO decarbonization measures will extend to all UNCLOS State Parties as “generally accepted international rules and standards”

As noted by ILA in 2003, generally accepted international rules and standards means those international rules, standards or regulations that bind States party to UNCLOS through international agreements, or bind States through customary law, or reflect State practice that has not necessarily matured into custom, that reflects UNCLOS standards. ILA further points out that “in many cases these will be those international rules, standards or regulations the International Maritime Organization establishes”. (Walker and Noyes, 2002) Furthermore, a report issued by the IMO Secretariat in 2014, Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization, explicitly identifies several conventions—including MARPOL 73/78—as meeting the criteria of “generally accepted international rules and standards” (IMO, 2014). The Opinion links the domestic legislation and enforcement of UNCLOS States Parties to international standards through its quotation of “generally accepted international rules and standards” and its elaboration on due diligence, legislative and enforcement obligations.

“International norms must always work their influence through the filter of domestic structures and domestic norms” (Finnemore and Sikkink, 1998). International law relies heavily on individual state enforcement on a reciprocal basis, whereas domestically, a legitimate central authority enforces the law (Oona, 2005). Therefore, the incorporation of international rules into domestic law ensures better compliance and implementation. This linkage thus paves the way for the effective implementation of IMO-led shipping decarbonization measures among UNCLOS States Parties.

3.3.1.1 Harmonization of domestic shipping legislation with international decarbonization rules and standards for UNCLOS States Parties

As discussed in the second part of the article, both the due diligence and legislative obligations require UNCLOS States Parties to enact domestic legislation on shipping decarbonization by international standards. The due diligence obligation requires States to establish national legislative, administrative, and enforcement mechanisms, the effectiveness of which must be evaluated against international climate frameworks such as the UNFCCC and the Paris Agreement, particularly the global temperature goal of limiting warming to 1.5°C above pre-industrial levels and the timeline for achieving emission reduction pathways (para. 243 of the Opinion).

Legislative obligation imposes more explicit criteria on States Parties, requiring their domestic laws “shall at least have the same effect as that of generally accepted international rules and standards established through the competent international organization or general diplomatic conference”. Although the ITLOS opinion specifically references MARPOL Annex VI, the interpretive scope of this provision remains subject to potential expansion. First, ITLOS narrowly focuses on the term “competent international organization” while leaving the term “general diplomatic conference” undefined. Scholarly commentary suggests that this phrase encompasses multilateral forums open to universal participation (Shabtai and Alexander, 1991), such as the United Nations General Assembly, the Conference of the Parties to the UN Framework Convention on Climate Change. Legally binding instruments adopted at such conferences may also qualify as “generally accepted international regulations and standards” under Article 211 of the UNCLOS. Second, the IMO’s “generally accepted regulations” and standards not only refer to formal treaties like MARPOL but also include resolutions adopted by IMO subsidiary bodies, such as the Marine Protection Committee (MPC) and MEPC (IMO, 2014) if they met the elements elaborated by ILA (Walker and Noyes, 2002). This broader interpretation aligns with the legislative goal of UNCLOS. UNCLOS intentionally incorporates external norms to address its inherent limitations in comprehensive ocean governance and to preserve collective maritime interests by preventing unilateral coastal state standards from fragmenting global governance (Qu, 2021). Through this “incorporation by reference” technique, UNCLOS dynamically binds States Parties to evolving international norms beyond its original text (Walker and Noyes, 2002).

ITLOS has identified IMO as the competent authority responsible for reducing GHG emissions from ships in the Opinion. Given the IMO’s experience and achievements in promoting anti-pollution measures for ships, along with the mandates of the Kyoto Protocol under UNFCCC[article 2(2)], the issue of shipping decarbonization is addressed through the IMO. This approach is also accepted by the international community (Chang et al., 2024; Sun, 2023). Under modern international law, only States Parties to IMO conventions or IMO member States are *prima facie* legally obligated to comply with IMO-adopted conventions and resolutions. However, through UNCLOS Article 211 (as interpreted by ITLOS) and its referential legislative framework, even a State that is neither an IMO member nor party to IMO conventions — provided it is a UNCLOS party State — must fulfill its treaty-based legislative obligation by incorporating rules in IMO conventions and resolutions on shipping decarbonization into domestic law once they constitute “generally accepted international rules and standards”. This mechanism ensures indirect compliance with IMO standards through domestic legal channels. Furthermore, UNCLOS States Parties are required to align their legislation with shipping

decarbonization rules promulgated through “general diplomatic conferences” (e.g., UNFCCC COP resolutions) if any, provided such rules attain the status of “generally accepted international standards” under UNCLOS Article 211(2).

3.3.1.2 Implementation of shipping decarbonization measures in international rules and standards for UNCLOS States Parties

As mandated by the enforcement obligation, UNCLOS States Parties are required to implement all necessary measures—legislative, administrative, and judicial—to ensure that vessels flying their flag or of their registry comply with applicable international rules and standards and their domestic laws, as well as regulations related to ship decarbonization. Since the “applicable” here equals to “generally accepted”, according to this obligation (Walker and Noyes, 2002), IMO-adopted conventions and resolutions on shipping decarbonization, once they are deemed as “generally accepted international rules and standards”, shall be enforced in UNCLOS States Parties.

Besides, the due diligence obligation also requires States Parties to effectively regulate both public and private entities to ensure their compliance with international regulations and standards. Notably, ITLOS has acknowledged GHG emissions as high-risk activities due to the foreseeable and significant harm they can inflict on the marine environment, as supported by the best available scientific evidence. Therefore, States are urged to exercise heightened due diligence in mitigating such harm to the marine environment. This standard of diligence should guide States in their efforts to address environmental damage. A failure by a State Party to adopt measures that meet this threshold, such as neglecting the precautionary principle, could constitute a breach of its due diligence obligations under UNCLOS.

In summary, by classifying GHG emissions as marine pollutants and certain IMO conventions as “generally accepted international rules and standards”, the ITLOS advisory opinion triggers a tripartite obligation structure for UNCLOS States Parties. States are obligated to take all measures to prevent, reduce, and control marine pollution from GHG emissions across all source (due diligence obligation); transpose IMO decarbonization instruments — including conventions, Assembly resolutions, and MEPC guidelines — into domestic law (legislative obligation); ensure compliance through robust legislative, administrative, and judicial mechanisms (enforcement obligation). These obligations constitute state obligations under UNCLOS, and non-compliance may expose states to international responsibility under the principle of *pacta sunt servanda* (the sanctity of treaties). While the ITLOS classification of GHG emissions as marine pollutants remains contentious, the risk of state liability incentivizes even non-IMO member states that are UNCLOS parties to align domestic legal and enforcement regimes with IMO standards. This alignment accelerates the pace and scope of global shipping decarbonization, enhancing the efficacy of the IMO’s regulatory framework.

3.3.2 The application of marine environmental protection obligations and compulsory dispute settlement under UNCLOS to GHGs control will ensure the effective implementation of shipping decarbonization measures

The impetus behind Advisory Opinion No. 31 stems, to some extent, from the perceived inadequacies of the global climate governance regime. International law without direct punitive mechanisms is often perceived as ineffective (Oona, 2005) (Oona). While the UNFCCC and its Kyoto Protocol imposed binding emission reduction targets on Annex I countries, the framework lacked precise implementation rules, rendering its overall binding character weak (Abbott and Snidal, 2000). The Paris Agreement further diluted this precision by adopting a system of nationally determined contributions, moving away from top-down mandatory targets towards a voluntary compliance model. This shift has resulted in even weaker treaty effectiveness. The lack of an effective enforcement mechanism of the UNFCCC, its Protocol, and the Paris Agreement significantly limits their binding force on contracting parties. Moreover, the decarbonization measures adopted or planned by the IMO are predominantly technical regulations and standards. They lack an integrated state responsibility mechanism, specific penalty provisions, and a compulsory dispute settlement framework.

In contrast, UNCLOS presents a more comprehensive and potent legal framework. The ITLOS Advisory Opinion establishes a critical linkage between GHGs control and UNCLOS by characterizing GHGs as pollutants to the marine environment. Part XII of UNCLOS imposes substantial and concrete substantive and procedural obligations on State Parties. Beyond the due diligence, legislative, and enforcement obligations specifically applicable to vessel carbon emissions mentioned at the beginning of this article, these include the general obligation to protect and preserve the marine environment (Article 192), the duty not to transfer damage or hazards or transform one type of pollution into another (Article 195), the obligation to co-operate on a global or regional basis (Article 197), and the obligation to monitor the risks or effects of pollution (Article 204), etc.

Besides the obligations, UNCLOS also provides legal consequences for States that breach those obligations—state responsibility and Liability. Pursuant to Article 235 of UNCLOS, States are responsible for fulfilling their international obligations concerning marine environmental protection. A failure to do so entails liability in accordance with international law. Furthermore, under paragraphs 2 and 3 of this article, State Parties must ensure that recourse is available under their domestic legal systems for prompt and adequate compensation or other relief for pollution damage caused by carbon emissions, in accordance with applicable international law. Furthermore, UNCLOS Part XV, along with Annexes VII and VIII, establishes compulsory procedures for the settlement of disputes relating to the law of the sea.

Particularly, the Opinion points out that, alongside the flag State, port States and coastal States also possess corresponding rights and bear obligations in controlling GHG emissions from

ships (para. 287 of the Opinion). Under Articles 218 and 220 of UNCLOS, both port and coastal States are granted investigation rights concerning the carbon emissions of vessels within their ports or offshore terminals. Where evidence warrants, a port State may institute proceedings against a vessel whose GHG emissions violate applicable international rules and standards, even if the violation occurred outside the State's internal waters, territorial sea, or exclusive economic zone. Moreover, if such emissions cause or threaten damage to a third State, the port State is obligated—upon request and as far as practicable—to investigate the violation. Similarly, a coastal State may institute proceedings where sufficient evidence establishes that a vessel within its territorial sea or exclusive economic zone has violated applicable international rules and standards. “Applicable” in Article 218 and 220 means the same as “generally accepted” where the word “applicable” modifies “international rules and standards” under UNCLOS (Walker and Noyes, 2002).

Consequently, by definitively characterizing GHGs as marine pollutants, the ITLOS Advisory Opinion creates a legal pathway for small island states. Specifically, they could initiate compulsory dispute settlement proceedings against State Parties for alleged violations of their obligations under Part XII of UNCLOS or for failures to adhere to “generally accepted rules and standards,” including those under MARPOL. Such proceedings could seek to establish state responsibility and secure corresponding economic compensation for climate-related damages to their marine environment (Kim and Kim, 2025). This integrated, legally robust mechanism offers a more viable pathway for ensuring the effective implementation of carbon reduction measures, potentially filling the enforcement gaps left by the climate-specific regimes.

4 Potential implications of the ITLOS Advisory Opinion No.31 on the maritime sectors

As a dynamic instrument, the law propels, shapes, and transforms the trajectory of socioeconomic development by establishing order, allocating rights and obligations, as well as guiding behavior. ITLOS's interpretation of States Parties' obligations regarding GHG emission reduction signals a paradigm shift toward stringent decarbonization requirements for the maritime sectors. It is expected to trigger repercussions across national shipping legislation and law enforcement, as well as the global shipping and port industries.

4.1 Implications on the shipping sector: acceleration and expansion of shipping decarbonization

The three obligations outlined in the Opinion ensure the global implementation of IMO regulations and standards concerning reducing GHG emissions from ships. During the MEPC 80

session in July 2023, IMO revised its decarbonization targets for the maritime industry, proposing increasing adoption of low/zero-carbon fuels. The updated framework mandates that zero/near-zero carbon emission technologies and green energy constitute 5% to 10% of the energy used by international shipping by 2030. It further requires to peak GHG emissions from international shipping as soon as possible and to reach net-zero GHG emissions by or around 2050, while considering different national circumstances (IMO, 2023). To achieve these targets, IMO collects data on both ship fuel standards and ship operation, introduces a ship energy efficiency rating mechanism, and implements a series of economic and legal measures, such as a shipping carbon emissions trading scheme. These instruments aim to align shipping industry practices with the Paris Agreement's temperature goals through measurable compliance mechanisms.

During the MEPC 83 held from April 7 to 11, 2025, IMO approved the Net-Zero Framework, which outlines key mid-term measures for shipping decarbonization. This Framework is scheduled for formal adoption at MEPC/ES.2 in October 2025 and anticipated to take effect in 2027. The framework includes the following elements: (1) Two tiers of targets for annual GHG fuel intensity (GFI) - a Base Target and a Direct Compliance Target will be set for compliance. (2) The global fuel standard for ships and a market-based Carbon Trading Mechanism for GHG emissions will be established. Shipowners exceeding compliance targets would be eligible to earn "surplus units" (SU), which are tradable on IMO-regulated platforms. Conversely, shipowners failing to meet targets must purchase Remedial Units (RUs) to offset excess emissions. (3) IMO Net-Zero Fund will be established to reward low-emission ships, support training, technology transfer, and capacity building to support the IMO GHG Strategy (IMO, 2025; IMO Secretariat, 2025). Confronting mounting international pressures for decarbonization, the shipping industry predominantly relies on three major emission reduction strategies:

4.1.1 Enhancing ship energy efficiency

As the most readily implementable near-term measure, improving vessel energy efficiency encompasses technological retrofits in ship design and construction to optimize performance and reduce carbon intensity. This includes streamlined hull designs, high-efficiency propellers, energy-saving devices, and accelerated phasing out of obsolete vessels. While these measures yield short-term emission reductions, their incremental improvements offer limited potential for achieving long-term, systemic decarbonization.

4.1.2 Optimizing ship operational management

Operational adjustments represent the most widely adopted approach for fleet emission mitigation, primarily through speed reduction and route optimization. Lowering cruising speeds reduces fuel consumption and emissions, but risks compromising logistical efficiency. Route optimization minimizes unnecessary nautical miles, thereby cutting emissions. However, the efficacy and applicability of these measures are constrained by market demand fluctuations, vessel scheduling complexities, and meteorological variables.

4.1.3 Scaling green fuel adoption

Large-scale use of green fuels is the cornerstone strategy for mid-to-long-term decarbonization in maritime transport. Green fuels, including liquefied natural gas (LNG), green hydrogen, green ammonia, green methanol, and other low-carbon or zero-carbon green fuels, can substantially cut GHG emissions. However, scaling green fuels faces many challenges, such as nascent production technologies, limited supply chains, and elevated costs. Nevertheless, in the long term, green fuel-powered vessels will be more competitive in the market under the incentive of the GHG emission pricing mechanism established by the IMO. Leading global carriers have proactively aligned their energy portfolios with this trajectory. In 2023, for instance, Mediterranean Shipping Company (MSC) ordered 18 LNG-powered vessels, representing 17.6% of its clean energy vessel orders over the past five years (2018–2023); Maersk ordered 34 methanol-fueled ships, constituting 58% of its clean energy fleet over the past five years; CMA CGM commissioned 18 LNG-fueled and 18 methanol-fueled vessels, accounting for 32.4% of its green fuel-powered ships over the past five years; COSCO Shipping ordered 6 LNG-powered and 5 methanol-fueled vessels, totaling 10.7% of its green vessel over the past five years; Hapag-Lloyd prioritized engine retrofits, modifying 60 vessels for methanol compatibility (SISI, 2024).

Technological revolutions and industrial transformations in the shipping industry will propagate to port operations through maritime logistics, offshore engineering, and energy infrastructure, necessitating strategic adaptations by port enterprises.

4.2 Implications on the port sector: green energy infrastructure deployment

The port sector is a critical downstream sector of the shipping industry. The decarbonization of shipping creates both challenges and opportunities for the port sector, necessitating comprehensive upgrades in environmental governance, technological capabilities, and industrial ecosystems of ports.

4.2.1 Infrastructure requirements

4.2.1.1 Lagging investments in decarbonization infrastructure

Current port infrastructure development fails to match projected demand. Clarksons Research data reveals only 273 ports globally offer LNG bunkering facilities, 251 have operational or planned shore power connections, and 29 provide methanol fueling capabilities (Gordon, 2024). With over 20% of global fleet capacity expected to adopt alternative fuels by 2030, critical gaps persist in green fuel supply chains and port infrastructure readiness.

4.2.1.2 Standardization challenges in new infrastructure

While the ITLOS Advisory Opinion catalyzes emission reduction timelines and the IMO sets decarbonization targets, neither establishes unified technical standards and operational norms for green vessels. Vessel-port interfaces. This regulatory

vacuum amplifies operational inefficiencies during infrastructure deployment, particularly undermining economies of scale. For instance, shore power systems face interoperability barriers: international vessels exhibit greater heterogeneity in technical parameters, such as power system frequencies and load capacities, compared to inland ships, resulting in much lower shore power utilization rates at coastal ports versus riverine counterparts.

4.2.2 Opportunities for investment in the development of strategic emerging industries

The green energy industry is a strategic emerging industry that drives the energy revolution, technological innovation, and socioeconomic development. In the context of shipping decarbonization, it also creates opportunities for port cities and enterprises to lay out strategic emerging industries.

4.2.2.1 Green fuel supply chain development

As alternative-fueled vessels proliferate, the refueling capacity for green fuels, including LNG, methanol, and ammonia etc., is becoming a key competitive indicator for ports. Pioneering hubs around the world like Rotterdam, Singapore, and Hamburg have been accelerating the construction of green energy refueling capacity in recent years to enhance the competitiveness of their ports. They have implemented refueling services for alternative fuels, including LNG, green methanol, and ammonia, researched into the technological applications of hydrogen, and provided multi-modal fueling solutions—including tanker truck terminals, tank swapping systems, shore-based bunkering, and ship-to-ship transfers. These capabilities significantly enhance port attractiveness for vessel callings and transshipment operations.

4.2.2.2 Integration of the energy and port sectors

Historically, there has been a low level of integration between the port and energy sectors, with port companies primarily focusing on fuel storage, bunkering services, and bulk commodity trading (Xue and Li, 2024). However, with the emerging trend towards green shipping and the need for an effective alternative energy supply, port corporations now regard vertical industry chain integration as a core strategy for cost reduction. For instance, Shanghai International Port Group (SIPG) has newly established an energy platform company whose business scope encompasses vessel port services, marine fuel sales, and new energy technology research and development. This entity plays a pivotal role in SIPG's development, and the integration model of "storage-transportation-supply" is redefining port business architectures in response to decarbonization pressure (Zhou and Gao, 2024).

In summary, by incorporating climate change issues within the framework of the law of the sea, the ITLOS Advisory Opinion No.31 has established more stringent environmental obligations for the maritime sectors. While debates persist regarding interpretive methodologies and legal effect, the Opinion has substantively heightened the urgency of compliance with vessel emission reduction mandates. Consequently, the shipping industry faces escalating emission regulations, necessitating expedited incorporation of IMO standards into national legislation.

Simultaneously, the port industry must address technological retrofit pressures, particularly in developing shore power systems and low-carbon fuel bunkering capabilities. More significantly, this development amplifies pressure for collective regional governance mechanisms. For port operators, achieving equilibrium between legal compliance and technological innovation becomes imperative to capitalize on these challenges as catalysts for the green transition.

5 Multi-level governance of shipping decarbonization in Hainan province and adaptive reform suggestions for Hainan ports

The international shipping decarbonization process, influenced by the ITLOS Advisory Opinion, is set to accelerate significantly under the leadership of the IMO. As a downstream sector of the shipping industry, the port sector has the opportunity to pioneer new pathways in this endeavor. Hainan, an exceptionally unique province of China, is strategically located at the southernmost point of the country, connecting the Pacific and Indian Oceans. It is adjacent to the Greater Bay Area and has strong connectivity to the market of Association of Southeast Asian Nations (ASEAN), facilitated by air and sea links with countries involved in the "Belt and Road" initiative. Additionally, Hainan is the only FTP in China, featuring some unique and essential tariff policies. Given these factors, this paper uses Hainan, a major port and maritime province of China, as a case study to analyze its policies in shipping decarbonization and offers suggestions for improvement of its port industry.

5.1 Multi-level governance of shipping decarbonization in Hainan province

The decarbonization of international shipping involves a multitude of actors across national borders. The contemporary maritime sector operates within a networked, cross-functional system governed by a multi-tiered legal and regulatory framework. This framework necessitates continuous negotiation among supranational, national, and local authorities, resulting from a broad reallocation of decision-making power. Consequently, the governance of shipping decarbonization involves the dynamic interaction of international rules, domestic laws, and sub-national policies. Each tier of jurisdiction is responsible not only for policy formulation but also for implementation and enforcement. While states retain a significant role, today's maritime governance is distinctly polycentric, characterized by cooperation among various national, regional, and local authorities, as well as international marine organizations.

At the international level, the shipping decarbonization process, significantly influenced by the ITLOS Advisory Opinion NO. 31, is poised to accelerate under the IMO's leadership, as we mentioned above. The Opinion creates a tangible link between climate action and the robust enforcement mechanisms of UNCLOS. States could

now reference their UNCLOS obligations within their NDCs, thereby strengthening the legal foundation for their emission policies. The Opinion's authority, though non-binding, exerts a "indirect constraint" through its functions as a subsidiary source of international law, compelling coastal and port states to strengthen port emission management. Furthermore, the Opinion may lead to subsequent litigation or arbitration (Buszman, 2024; Klerk, 2025), and relevant organizations may use this as a basis to require port states or coastal states to strengthen port carbon emission management. The likelihood of such an outcome will become significantly greater following the ICJ's issuance of a similar advisory opinion in 2025. If China or Hainan fails to adjust in time, it may be passive in future international litigation.

At the national level, although the Chinese government does not recognize the advisory competence of the full Tribunal, it has, as a responsible developing nation, actively engaged in international cooperation and implemented concrete domestic actions to address climate change. China maintains that the UNFCCC, its Kyoto Protocol and Paris Agreement constitute the legal framework and the principle of common but differentiated responsibilities must always serve as the guiding principle for addressing climate change. Basing on that, China has been taking legislative, judicial and policy measures action targets, to comprehensively tackle climate change in an effort to fulfill its commitments under the UNFCCC and accomplish domestic climate. In 2020, President Xi Jinping announced China's targets for carbon peaking and carbon neutrality. In 2021, China released two documents, "Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy" and "Action Plans for Carbon Dioxide Peaking Before 2030". In 2022, the Ministry of Ecology and Environment carried out work related to the preparation of the "National Climate Change Adaptation Strategy 2035". Under the guidance of these policies, different industries, sectors, and localities have formulated their implementation plans. Domestic policy instruments are more commonly used in this field. However, the formulation and amendment of relevant laws and administrative regulations have yet to be implemented (Qian et al., 2024; Zeng and Wang, 2025). Under this background, provincial governments, particularly Hainan FTP, may still incorporate international rules and standards into local practical policies through legislative experiments. The path of "localization of international rules" not only safeguards national sovereignty but also promotes the global governance agenda, providing a feasible solution for developing countries to deal with the "climate responsibility trap".

At the provincial level, in 2022, during an inspection in Hainan, President Xi emphasized Hainan's need to focus on several key areas: revitalizing ports, developing transportation industries, refining its strategic positioning, enhancing adaptability, prioritizing green development and ecological conservation, and aligning port development with the construction of the FTP (Department of Infrastructure Development, 2022). The Overall Plan for the Construction of Hainan Free Trade Port further stresses the importance of expanding the maritime services value chain, strengthening global supply chain management capabilities,

and establishing an international shipping hub (Xinhua News Agency, 2020). Given Hainan's national strategic importance and the current state of its port development, ports of this province should focus not on simply increasing cargo throughput or physical size but on leveraging the FTP policy framework through a "differentiated development" strategy. This approach aims to create world-class green ports, thereby maintaining their competitive edge in global markets. In terms of local legislation, Hainan Free Trade Port Ship Navigation Management Measures implemented in 2024 further refine ship emission control, anti-fouling equipment standards, and emergency response mechanisms. It also requires compulsory reporting of vessels, which corresponds directly to the requirement of Article 194 of UNCLOS for the "adoption of generally accepted international rules and standards". As the only global FTP in China, Hainan Province's Several Provisions on the Management of Safe Access to the Inbound Environment (implemented in 2025) requires enterprises to formulate pollution prevention and control plans to ensure that exhaust gas and wastewater are discharged up to standard and control emissions at a reasonable level. These regulations are directly linked to the 'prevention and control of ship pollution' required by Opinion. Such measures are both in line with UNCLOS obligations and in response to Opinion's requirement for control of marine pollution at source. Therefore, through "convention - domestic law - local policy" to influence China's provincial governance, Hainan Province's port governance reform has shown the characteristics of "domestication of international rules and standardization of local practices". As a key hub and free trade port, Hainan's adaptive adjustment of port governance stems from international legal pressures and is deeply coupled with domestic policy goals. One of the goals of Hainan Free Trade Port is to establish regulatory standards that are in line with international standards,¹ and the ITLOS opinion provides a rule reference for it. In the future, it is necessary to further improve the international standard-local policy transmission mechanism, such as incorporating Opinion recommendations into the revision of the Hainan Free Trade Port Construction Master Plan and strengthen technological innovation and capacity building.

5.2 Aligning with global green shipping fuel pathways to establish an international green energy refueling hub

The substitution of traditional fossil fuels with green and clean energy represents the fundamental long-term strategy for achieving emission reduction targets in the shipping industry. Hainan possesses distinct advantages in green energy production, logistics, and tax incentives, which enable a low-cost, closed-loop system spanning production, consumption, and distribution. This positions Hainan to explore the development of an international green energy bunkering hub. Accordingly, port enterprises should

¹ Measures for the Administration of Ship Navigation in Hainan Free Trade Port. Qiong Fu Ban [2024] No. 3.

closely monitor global energy technology trends, track shifts in green vessel orders, scientifically forecast future demand for green vessels and energy, and actively promote the construction of an international green energy refueling hub. Current developments in green fuels are outlined below.

5.2.1 LNG as a marine fuel has achieved initial global adoption

Among mainstream clean marine fuels, China Classification Society (CCS) evaluates LNG as the most viable short-term option based on availability, cost-effectiveness, technological maturity, environmental performance, and regulatory compliance (CCS, 2023). According to DNV, “Using LNG and bio-LNG is the least-costly option as using fossil LNG gives lower well-to-wake GHG intensity than required until 2035” (Bush, 2024). Consequently, major shipping companies accelerate LNG vessel construction, driving projected growth in LNG bunkering demand. Clarksons Research data indicates that across 2024, 820 vessels ordered involving alternative fuel capability, which representing 50% of all ships ordered. Among these, LNG-fueled vessel orders reach 390, representing 47% of the total (Clarksons, 2025).

5.2.2 Methanol emerges as a critical mid-term decarbonization fuel

Under lifecycle GHG emission frameworks, green methanol achieves 63%–99% emission reductions and is positioned as a key alternative fuel for deep decarbonization (IMO, 2023). While international standards for green methanol remain stringent, regulatory flexibility is emerging. The EU’s Renewable Energy Directive (RED II) amendments now recognize methanol produced using carbon captured from industrial and power plant emissions as “green,” alongside bio-methanol and e-methanol. Globally, nearly 30 methanol-fueled vessels are operational, with over 220 new orders (including 150 container ships) placed by November 2023. Vessel Methanol bunkering volumes reached 93,900 metric tons in 2023, a 165% year-on-year increase. Industry efforts are expanding methanol engine portfolios, developing fuel supply systems, and planning bunkering infrastructure (China Ship Inspection, 2024). Most green methanol production projects are currently situated in China, Northern Europe, and North America. Major global bunkering hubs such as Singapore and the United Arab Emirates face challenges due to higher costs associated with long-distance transportation. Therefore, developing green methanol in China has comparative advantages.

5.2.3 Long-term prospects: green hydrogen and green ammonia as key zero-carbon solutions for shipping

The Energy Law of the People’s Republic of China, enacted on November 8, 2024, formally incorporates hydrogen energy into the national energy administrative framework. This legislative development signifies China’s commitment to establishing comprehensive hydrogen energy reserves and emergency response systems in the future.

Globally, while green hydrogen currently faces challenges, including technological immaturity, high costs, underdeveloped infrastructure, and stringent safety requirements, it possesses substantial application potential across industrial and transportation sectors. Significant cost reductions for green hydrogen are anticipated as technological advancements progress and production scales increase. Notably, Germany, Canada, the United Arab Emirates, and the European Union have all formulated national or regional hydrogen strategies (ZHFCA, 2021). Singapore exemplifies proactive engagement in green hydrogen research through collaboration with research institutions. The nation is implementing research projects focused on establishing price-competitive hydrogen utilization for shipping. These initiatives comprehensively address the entire supply chain—encompassing hydrogen production/procurement, storage, and transportation—to develop a “robust and competitive” hydrogen ecosystem. Furthermore, with investment from sovereign wealth fund GIC, Singapore has launched scaled green hydrogen and ammonia production projects (Atchison, 2022). Although hydrogen-fueled vessels currently represent a small fraction (1%) of new ship orders placed in 2024 (Clarksons, 2025), Clarksons forecasts that hydrogen will power 40% of alternative-fueled vessels by 2050 (CCS, 2021).

Besides green hydrogen, green ammonia produced through renewable electricity achieves emission reductions of 93% to 100% according to the IMO’s lifecycle carbon accounting rules. Consequently, green ammonia production and supply have become a primary global focus. The International Energy Agency (IEA) projects annual global green ammonia production will reach 15 million tons by 2030 and surge to 71 million tons by 2040 (Bora et al., 2024). According to the China Classification Society (CCS), China’s current pipeline of green ammonia production facilities under construction or planning has a combined annual capacity exceeding 8 million tons (CCS, 2023). Presently, significant research and development efforts on ammonia-fueled engines, vessels, and associated standards and regulations are underway in China, Japan, South Korea, European countries, and other regions.

5.2.4 Green energy advantages of Hainan province

Hainan Province possesses abundant renewable energy resources, such as wind and solar power, which provide it with a distinct international comparative advantage in producing green shipping fuels. In 2024, the Hainan Provincial Government issued the Three-Year Action Plan for High-Quality Development of the Marine Economy and Advancing the Construction of a Strong Marine Province (2024–2026), which prioritizes the development of the offshore wind power industry chain as a key focus for Hainan Province (General Office of Hainan Government, 2024). Specifically, during the 14th Five-Year Plan period, Hainan has planned the construction of 11 offshore wind farms (Qiao, 2024). Furthermore, as early as 2022, the Hainan Provincial Wind Power Equipment Industry Development Plan (2022–2025), issued by the Hainan Provincial Department of Industry and Information Technology, established the “one industrial park and two manufacturing bases” spatial layout for the province’s wind power

equipment manufacturing industry. This layout comprises explicitly the Western Hainan Offshore Wind Power Industrial Park, alongside the Danzhou and Dongfang Offshore Wind Power Equipment Manufacturing Bases (Hainan Daily, 2022). Building upon this foundation, on November 5th, 2024, Siemens Energy signed cooperation agreements with Shenergy Co., Ltd., China Energy Group Hainan Company, and China Datang Group Hainan Company. These agreements aim to jointly advance the production of green hydrogen and green methanol from offshore wind power in Hainan, thereby supporting the development of the province's green energy industry (Hainan Daily, 2024).

Based on these existing achievements and advantages, Hainan Province could leverage its institutional and policy frameworks for FTP to support the establishment of green methanol and green hydrogen production and bunkering bases in this province, as well as research on methanol and hydrogen production from offshore wind power.

Moreover, as China's only FTP, Hainan offers significant tax preference for fuel bunkering. Presently, bonded fuel oil and bonded LNG bunkering services are explicitly included in the Hainan Free Trade Port Encouraged Industries Catalog (2024 Edition). Drawing on the experience of international shipping centers like Singapore and Rotterdam in developing global energy bunkering hubs, Hainan Province should actively promote the implementation of tax-free bunkering for other green fuels and expedite the development of a comprehensive green energy production, supply, trade, and transaction industrial chain.

5.3 Leveraging regional port cooperation mechanisms in the South China Sea for collaborative development of green shipping corridor initiatives

A Green Shipping Corridor (GSC) represents a zero-emission shipping route established between two or more ports through management innovations, adoption of new technologies, and the use of green fuels. Critically, this model engages ports, shipping companies, and fuel suppliers operating along the corridor and is widely recognized as an effective mechanism for advancing maritime decarbonization (Ismail et al., 2024). To promote the construction of green shipping corridors, 22 countries signed the Clydebank Declaration during the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change. Through this Declaration, signatories committed to establishing at least six GSCs between two or more ports globally by 2025, with a further commitment to significantly expand the number of such corridors by 2030.

GSCs not only accelerate decarbonization within the shipping industry and address the climate crisis but also yield significant economic and political benefits. Economically, they stimulate the creation of "green" jobs and catalyze industrial upgrading (Akhavan, 2025). Politically, they present a critical opportunity to reshape global shipping governance frameworks and international

standards. Given these multifaceted benefits, most maritime states are actively engaging in collaborative GSC initiatives.

5.3.1 Current green corridor initiatives with participation of Chinese ports

Currently, numerous ports worldwide, including those in China, are actively contributing to maritime decarbonization efforts by enhancing the integrated use of green energy and participating in GSC development. According to the 2024 Annual Progress Report on Green Shipping Corridors (hereinafter referred to as "2024 GSC Report"), as of November 2024, the global tally of GSC initiatives has reached 62 (Getting to Zero Coalition and Global Maritime Forum, 2024). Geographically, European regions account for approximately one-third of these projects, while the North Pacific and Asia-Pacific regions each represent roughly one-fifth (Getting to Zero Coalition and Global Maritime Forum, 2024). Further expanding this network, in May 2025, Ningbo-Zhoushan Port of China signed agreements with the Port of Valencia (Spain), Port of Hamburg (Germany), and Port of Wilhelmshaven (Germany) to jointly establish new GSCs, thereby adding three new GSC routes. Table 1 details GSC initiatives collaboratively developed with the participation of Chinese ports and the progress phases of each corridor:

In the first column of the table, those GSCs established before 2025 are sourced from the 2024 GSC Report, while those initiated after 2025 were collected by the author through online research. The criteria for selecting these corridors align with those defined in the 2024 GSC Report, according to which, a GSC must: a, work toward the use of zero-emission fuel or energy for primary ship propulsion; b, support the commercialization of non-commercial fuels or energy sources in shipping; c, feature a high level of cross-value chain collaboration; d, call itself a green corridor from the point of initiation; e, with a focus on zero-emission ocean-going vessels. Detailed information regarding each corridor, provided in the second column, was obtained as follows: for the GSCs participated by Ningbo-Zhoushan Port, official MoUs served as the source; for all other corridors, information was gathered from disclosures on official port or government websites. The phase classifications shown in the third column are based on the framework outlined in the 2024 GSC Report. It adopts an approach to measuring corridor progress which includes four phases: Initiation - Exploration (Early, Advanced) - Preparation (Pre-commercial, Commercial) - Realization (Construction, Operation). Each phase is marked by characteristic activities. The specific phase assigned to each corridor was determined by the author through evaluating actions reported by the relevant ports—collected via online sources—against the established phase criteria.

5.3.2 Strategic pathways for Hainan province

As of now, ports in Hainan Province have not participated in any Global Supply Chain (GSC) initiatives. Given the current global situation regarding port development, it is recommended that Hainan Province strategically select one port in the South China Sea region to collaborate on establishing a GSC. This would serve as

TABLE 1 Green shipping corridor initiatives with participation of chinese ports².

No.	GSCs	Details	Corridor progress phases
1	Shanghai–Los Angeles/Long Beach;GSCs	This corridor was initiated in 2022. Shanghai–Los Angeles/Long Beach is one of the world's busiest cargo routes. Pursuant to the Implementation Plan Outline for this Corridor, shipping line partners on this route will deploy vessels capable of achieving either low or zero well-to-wake emissions within the corridor commencing in 2025. Furthermore, by 2030, the corridor will demonstrate the viability of deploying the world's first well-to-wake zero-emission container vessel (or vessel fleet). To advance these objectives, the Port of Shanghai and the Port of Los Angeles have established consensus on multiple collaborative fronts, including but not limited to pilot applications of alternative marine fuels such as green methanol, utilization of shore power for vessels, and development of intelligent terminal infrastructure (C40 Cities, 2023).	Realization (Construction: key assets built)
2	Shanghai–Hamburg GSC	According to the Memorandum of Cooperation signed by the two ports in 2024, all parties will cooperate to promote the construction and use of onshore power at terminals; explore and promote the construction of necessary infrastructure, regulations, and preferential policies for the supply, use, and bunkering of green fuels; invite more partners to participate and jointly commit to achieving the goals of the green shipping corridor; and share knowledge and information to spread and expand the benefits of the green shipping corridor.	Exploration (Early: aligning on what the opportunity looks like)
3	Shandong– Singapore GDSC	In October 2024, the Maritime and Port Authority (MPA) of Singapore and the Transportation Department of Shandong Province signed a Memorandum of Cooperation to jointly establish the Singapore-Shandong Green and Digital Shipping Corridor. The cooperation aims to leverage the growing trade and shipping volume between Singapore and Shandong and promote the sustainable development of the shipping industry between Singapore and the Bohai and Yellow Sea regions by promoting digital and green solutions. The cooperation areas include exploring green technologies, safety operation training for alternative fuels, digital information exchange for port operations, knowledge sharing on shore power technology, etc.	Exploration (Advanced: understanding what needs to happen to realize the opportunity)
4	Tianjin–Singapore GDSC	Tianjin Port took the lead in building the world's first "Smart Zero-Carbon Terminal". In 2023, the MPA of Singapore and the Tianjin Municipal Transport Commission executed a Memorandum of Cooperation on GDSC, under which both parties will jointly advance the development of a Tianjin–Singapore GDSC. In the realm of green shipping, this initiative advances the realization of low-carbon and zero-carbon emission fuel supply and bunkering infrastructure development in Singapore and Tianjin.	Preparation (Pre-commercial: removing shared barriers to realization)
5	Guangzhou–Los Angeles GSC	In 2023, the Port of Guangzhou and the Port of Los Angeles executed a Memorandum of Cooperation in Los Angeles, whereby both parties committed to establishing a Trans-Pacific Green Shipping Corridor. This initiative aims to reduce greenhouse gas emissions along their respective trade routes while advancing the adoption of low- and zero-carbon vessels and fuels.	Exploration (Early: aligning on what the opportunity looks like)
6	Ningbo-Zhoushan–Hamburg GSC	In May 2025, the Port of Ningbo-Zhoushan and the Port of Hamburg signed a Memorandum of Understanding on the Establishment of a Green Shipping Corridor. The Parties aim to jointly accelerate shipping decarbonization by working with stakeholders to enable ships calling at the Port of Ningbo Zhoushan and the Port of Hamburg to achieve net-zero emissions by the earliest feasible date. The related actions include	Exploration (Early: aligning on what the opportunity looks like)

(Continued)

² Informations regarding Ningbo -Zhoushan Port related GSCs come from official MoU and Initiatives signed by the parties.

TABLE 1 Continued

No.	GSCs	Details	Corridor progress phases
		the construction of shore power infrastructure, the application of related policies, and the application of shore power and low/zero-carbon fuels by vessels and port operations.	
7	Ningbo-Zhoushan–Valencia GSC	In May 2025, Ningbo Zhoushan Port signed two initiatives separately with the Port of Valencia and the Port of Wilhelmshaven for building green shipping corridors along the two routes. The two initiatives aim to construct the gate-to-gate green shipping corridors between the container terminals agreed upon by the three ports. The key decarbonization actions will focus on the construction of shore power infrastructure, the application of shore power and low/zero-carbon fuels by vessels and port operations, etc.	Exploration (Early: aligning on what the opportunity looks like)
8	Ningbo-Zhoushan–Wilhelmshaven GSC		Exploration (Early: aligning on what the opportunity looks like)

a preliminary step toward developing an international green fuel bunkering hub. The reasons for this recommendation are as follows:

Firstly, positioned within China’s vital South China Sea shipping lanes, Hainan Province serves as a critical nexus connecting the Pacific and Indian Oceans. Secondly, its proximity to the Guangdong-Hong Kong-Macao Greater Bay Area and its capacity to access ASEAN markets establish Hainan at the strategic intersection of the world’s most dynamic domestic market and the burgeoning Southeast Asian market. Thirdly, shipping routes traversing Hainan’s waters primarily comprise domestic routes and routes to East Asia and Southeast Asia. Notably, China has already established mature port cooperation mechanisms with other nations in the South China Sea, which include the Memorandum of Understanding on China-ASEAN Transportation Cooperation (2004),³ the China-ASEAN Maritime Consultation Mechanism (2005), the Joint Statement on China-ASEAN Port Development and Cooperation (2007),⁴ the China-ASEAN Maritime Transport Agreement (2007), the China-ASEAN Senior Officials’ Meeting on Port Cooperation (2008). All these frameworks explicitly address cooperation on port affairs between China and ASEAN. Besides, the China-ASEAN Maritime Cooperation Fund (2011) provides crucial financial support for regional port collaboration. Thus, Hainan’s ports should actively utilize these existing regional port cooperation frameworks to initiate GSC initiatives with leading ports across the region.

Among the numerous ports in this region, Singapore and Malaysian ports possess comparatively advanced infrastructure, making them well-suited to meet the requirements for establishing green corridors. In 2015, China and Malaysia signed their first port cooperation agreement, the Memorandum of Understanding on the Establishment of a Port Alliance, forming the “China-Malaysia Port Alliance” and thus laying a solid foundation for collaboration.

Singapore, as a globally preeminent shipping hub, is an important node on the trans-Pacific route. Singapore port utilizes its geographical advantages and well-developed foundations in industry, petroleum refining, shipbuilding/repair, electronics, and service sectors to achieve world-leading levels in port operations, shipping services, and port-centric urban development. Singapore Port is also a promoter of the green transformation of the shipping industry. In recent years, it has strengthened exchanges and

cooperation with multiple international ports to jointly accelerate the construction of green and digital shipping corridors worldwide, making positive contributions to the sustainable development of international shipping and the innovative development of the global supply chain. It has proactively developed dedicated decarbonization strategies: the “Maritime Singapore Green Initiative” (MPA Singapore, 2025a) and the “Singapore Maritime Decarbonization Blueprint: Working Towards 2050.” (MPA Singapore, 2025b). These programs aim to align Singapore’s maritime policies with the United Nations Sustainable Development Goals and the IMO’s decarbonization targets, ensuring Singapore retains its status as a leading global maritime hub. [1] Therefore, Singapore possesses both the requisite capabilities and a strategic interest in establishing green shipping corridors.

“Fundamentally, establishing a green shipping corridor creates a special targeted area. Within this area, stakeholder demands can be aggregated at maximum speed and efficiency, allowing for the development of fuel production and port infrastructure to be improved, while facilitating the implementation of related policies, regulations, and safety procedures.” (Zheng et al., 2024) Hainan Province should leverage existing port cooperation mechanisms within the South China Sea region to actively promote clean and low-carbon port-to-port cargo transportation. By establishing GSCs between relevant ports, Hainan can thereby enhance its standing and influence across the region.

5.4 Exploring green fuel standards and strengthening Hainan’s influence in the carbon trading governance by leveraging FTP’s pilot reform advantages

Capitalizing on its policy advantages in shipping taxation and port services, the Hainan FTP should proactively utilize its unique status to advocate for national-level pilot programs and supportive policies regarding green energy supply in shipping. Currently, beyond the Shanghai region, China has not formally included the shipping industry within its carbon trading system. Furthermore, a comprehensive legal framework for green energy certification in shipping fuels, encompassing rules, standards, and methodologies,

remains underdeveloped, and specialized certification authorities are lacking. To safeguard China's green and low-carbon shipping development and protect the vital interests of domestic new and clean energy producers, it is imperative to expedite the development of a related regulatory and standards system, while carefully considering national conditions. This includes pursuing mutual recognition of Chinese and foreign green energy certification standards, as well as constructing a standards framework compatible with global benchmarks. Therefore, building upon the pilot and demonstration mandate of FTP, Hainan Province is recommended to explore and refine frameworks for standards governing green methanol, green hydrogen, and similar fuels, as well as associated bunkering standards and carbon taxation mechanisms, through the existing regional port cooperation mechanisms mentioned above. Establishing and formalizing these systems will enable Hainan to secure greater initiative and influence within the international shipping industry.

On the international front, the MEPC of IMO is scheduled to adopt amendments to MARPOL Annex VI – constituting mid-term GHG reduction measures – during its intersessional meeting in October 2025, with implementation planned for 2027. As a Category A member of the IMO Council, China should effectively utilize its influence to capitalize on this crucial opportunity. This necessitates enhanced collaboration among maritime administrations, port and shipping enterprises, as well as research institutions to conduct focused studies on emission data accounting and data protection under the IMO's Guidelines on Life Cycle GHG Intensity of Marine Fuels (LCA Guidelines), the technical, legal, and economic implications of the mid-term measures; and the adequacy of support provisions for developing countries. Based on this research, China should formulate and submit rational proposals to MEPC. Given its status as a significant maritime province, Hainan should actively participate in these critical research efforts. Concurrently, it should proactively interface with relevant competent authorities, such as the Maritime Safety Administration (MSA) of the Ministry of Transport, to secure designation for pilot programs on green energy applications in shipping, as well as related research and policy support.

5.5 Enhancing the capacity of port enterprises to respond to international climate change litigation

The opinion may catalyze climate litigation domestically and internationally (Buszman, 2024; Klerk, 2025). International climate-change litigation poses significant challenges for Chinese enterprises. The ITLOS Advisory Opinion clarifies that, in order to address global

climate change, States Parties to UNCLOS have legal obligations to reduce GHG emissions to the marine environment, thereby raising the stakes for national legislation and regulation and, in turn, reshaping the business environment and the legal risks that enterprises face. This development elevates the legal implications for national climate policies and legislation, directly impacting the operational environment and legal exposure of enterprises operating internationally (Wang, 2023). To help domestic enterprises navigate this evolving landscape, China must refine its legal framework—particularly the Company Law and related statutes—to embed explicit climate-related duties, enhance corporate compliance, and facilitate enterprise-level risk mitigation (Zeng and Wang, 2025).

In the context of international climate litigation, corporate environmental responsibility is subject to intense scrutiny (Mandal, 2022). Enterprises must therefore implement a comprehensive environmental management system (EMS) that is aligned with ISO 14001 or equivalent standards, conduct regular environmental risk assessments covering the full life cycle of their operations, and adopt comprehensive measures to protect the environment (Balakin, 2023). Moreover, enterprises should also integrate environmental policies into their business operations, encompassing production, waste management, and disposal (Sun et al., 2024). These actions not only enhance corporate environmental reputation but also provide critical, concrete evidence in litigation, demonstrating proactive efforts to minimize environmental impact.

As for port enterprises specifically, since port enterprises are accelerating integration within the energy sector and playing pivotal roles in the development of clean energy supply and infrastructure, as we mentioned above, against the backdrop of the ITLOS Advisory Opinion and the rising trend of international climate litigation, these enterprises should also prioritize effective risk management. This necessitates comprehensive oversight of port equipment and infrastructure operations, as well as accurate monitoring and assessment of all port facilities. Additionally, it requires proactive identification of operational risks and the development and implementation of robust contingency plans and risk mitigation strategies. Furthermore, port operators should continually recalibrate their operational and managerial practices by evolving national legislation and administrative guidance (e.g., carbon market expansion, stricter port emission standards, and mandatory climate-related disclosure rules) (Greg and Shivaprakash, 2021). By institutionalizing these measures, port enterprises—and, by extension, other climate-exposed sectors—will not only reduce litigation exposure but also strengthen their competitive position in the low-carbon global economy.

6 Conclusion

While ITLOS Advisory Opinion No. 31 is not legally binding, it may produce indirect legal effects as a subsidiary means of legal interpretation. Should the decarbonization measures developed by the IMO constitute “generally accepted international rules and standards,” UNCLOS State Parties would assume a direct obligation to implement them, as well as an indirect obligation to

3 Memorandum of Understanding Between the Governments of the Member Countries of the Association of Southeast Asian Nations and the Government of the People's Republic of China on Transport Cooperation.

4 Agreement on Maritime Transport Between the Governments of the Member Countries of Association of Southeast Asian Nations and the Government of the People's Republic of China.

comply by incorporating them into domestic law. Under special mechanism designed by UNCLOS, IMO decarbonization initiatives will extend to all UNCLOS state parties, and the application of marine environmental protection obligations and compulsory dispute settlement under UNCLOS to GHGs control will ensure the effective implementation of shipping decarbonization measures. Following the ITLOS Opinion, the international shipping decarbonization process, led by the IMO, is likely to enter an accelerated phase. The port industry, as a downstream sector of the shipping industry, presents an opportunity to establish a new trajectory. In alignment with the global decarbonization trend, in July 2024, the Chinese government issued the Opinion on Accelerating the Comprehensive Green Transformation in Economic and Social Development. This document explicitly calls for the vigorous development of non-fossil energy, the construction of green transportation infrastructure, including ports, and the promotion of green vessels. It also highlights China's leadership in the global green transition, guided by the concept of "a community with a shared future for mankind." This policy document not only responds to emerging international decarbonization requirements but also outlines the strategic course for China's future shipping decarbonization efforts.

Against this backdrop, Hainan Province is well-positioned to lead this transition. As a major maritime and port province, it possesses abundant wind and solar resources for producing green fuels. As a pivotal hub in South China Sea shipping lanes, it offers inherent geographical advantages for developing into an energy bunkering island. As China's sole FTP, it benefits from parallel policy leverage to advance green fuel bunkering and establish standards frameworks, as well as directly align international decarbonization standards with local policies. As a key participant in South China Sea regional port cooperation mechanisms, it possesses the institutional foundation to pioneer GSC initiatives.

Consequently, by proactively positioning Hainan to be a world-class green energy bunkering hub, the province can achieve a transformative leapfrog advancement in global port competitiveness. The application of green fuels puts new demands on port refueling facilities. The provision of safe, reliable, high-quality, and low-priced fuel "one-stop" services at a high standard will become a core competitiveness of international shipping centers.

Author contributions

TW: Resources, Methodology, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition, Supervision. YS: Supervision, Investigation, Writing – review & editing, Resources.

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Funding

The author(s) declare financial support was received for the research and/or publication of this article. This research was funded by the Philosophy & Society Planning Project of Zhejiang Province: (Grant No.19NDQN322YB) Litigation Mechanisms for Marine Ecological Damage Compensation in Zhejiang Province; the industry-sponsored Project: (Grant No.HX2022000310) Research on the Legal System for Claims Settlement of the Ship-source Oil Pollution Fund.

Acknowledgments

Special appreciation is extended to Professor Julia Xue for her guidance and encouragement during my tenure as a visiting scholar. Additionally, I wish to express sincere gratitude to Mr. Pangao Li for his invaluable support throughout this research, particularly for sharing critical insights on port development strategy.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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