BRI International Green Development Coalition
2021 Policy Study Series

Study on the Green Development of BRI Maritime Connectivity

In April 2019, Chinese and international partners officially launched the BRI International Green Development Coalition (BRIGC) at the Second Belt and Road Forums for International Cooperation. BRIGC aims to establish a policy dialogue and communication platform, an environmental knowledge and information platform, and a green technology exchange and transfer platform, so as to advance global consensus, understanding, cooperation, and action of a green Belt and Road Initiative (BRI).

Oceans are of critical significance to the survival and development of human societies. It has great potentials for climate change mitigation and adaptation and provides solutions to address food security and poverty among other challenges. In 2015, the UN released the 2030 Agenda for Sustainable Development, identifying "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" as one of the 17 Sustainable Development Goals (SDGs). With the deepening of economic globalization and regional economic integration, cooperation on the market, technologies, and information is increasingly close with the ocean as the carrier and link. Developing the blue economy has gradually become an international consensus. Augmenting marine cooperation is a necessity to bond up the world economy, deepen reciprocal cooperation, and widen the development space. It also marks a significant frontier for the participating countries of the Belt and Road Initiative (BRI) to address crises and challenges, and facilitate regional peace and stability.

In light of this context, through reviewing and summarizing the current status and issues of China and BRI participating countries in constructing green ports, developing green shipping, and conserving marine biodiversity, this report analyzed the strategy and goal for the international shipping industry to address climate change, proposed the pathway and measures for emission reduction in the shipping industry, compared and analyzed the cases and experience from China and BRI participating countries in developing green ports and green shipping, and came up with policy recommendation for realizing maritime connectivity and green development under the Belt and Road Initiative in the hope of providing reference for the government, industry organizations, and businesses.

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Executive Summary

Oceans are of critical significance to the survival and development of human societies. It has great potentials for climate change mitigation and adaptation and provides solutions to address food security and poverty among other challenges. In 2015, the UN released the 2030 Agenda for Sustainable Development, identifying "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" as one of the 17 Sustainable Development Goals (SDGs). With the deepening of economic globalization and regional economic integration, cooperation on the market, technologies, and information is increasingly close with the ocean as the carrier and link. Developing the blue economy has gradually become an international consensus. Augmenting marine cooperation is a necessity to bond up the world economy, deepen reciprocal cooperation, and widen the development space. It also marks a significant frontier for the participating countries of the Belt and Road Initiative (BRI) to address crises and challenges, and facilitate regional peace and stability.

The port and shipping industry are the boosters of world trade and economic development; Meanwhile, ocean transportation is also an important source of greenhouse gas emissions. Despite an urgent need for carbon reduction in the shipping industry, policies on carbon reduction in the shipping industry are not prioritized across countries. Only 5 out of 23 Maritime Silk Road countries have incorporated the shipping industry in Nationally Determined Contributions (NDC). The port is an integral component for infrastructure connectivity under the Belt and Road Initiative, as well as the foundation for the development of the global shipping industry. Constructing green ports could both stimulate the potentials of green shipping and catalyze the deep transformation of the industry chain. In the context of a global change, the conservation of marine biodiversity is confronted with multiple challenges, including the negative impacts of overfishing on marine resources, marine ecosystem, and biodiversity, ocean acidification and the decline of coral reef ecosystems caused by climate change, and marine environmental pollution from the exploration and development of ocean resources and tourism activities.

In light of this context, through reviewing and summarizing the current status and issues of China and BRI participating countries in constructing green ports, developing green shipping, and conserving marine biodiversity, this report analyzed the strategy and goal for the international shipping industry to address climate change, proposed the pathway and measures for emission reduction in the shipping industry, compared and analyzed the cases and experience from China and BRI participating countries in developing green ports and green shipping, and came up with policy recommendation for realizing maritime connectivity and green development under the Belt and Road Initiative in the hope of providing reference for the government, industry organizations, and businesses.

Chapter I. Introduction

1. Research Background and Significance

Occupying over 70% of the surface of the earth, the ocean is of vital significance to the survival and development of human beings and creatures. It provides oxygen, food, and medicines among other products as well as the essential ecosystem service. It determines the climate and weather in the local, regional, and global range. It also composes the foundation of traditional industries such as energy, trade, transportation, etc., and emerging industries. The ocean is the basis of human production and development. The development of human societies depends on the quality of marine resources and the environment to a large extent. The marine ecosystem is the largest continuous ecosystem on the earth, home to high-productive offshore habitats and seabed biodiversity habits. The past centuries have witnessed the growing strategic significance of the ocean in fishing, shipping, military, entertainment, conservancy, and oil and gas development. It is closely related to global food, energy, transportation, and climate safety with foreseeable growing significance in our efforts to cope with future global challenges.

In 2013, Chinese President Xi Jinping proposed to jointly build the Silk Road Economic Belt and the 21st Century Maritime Silk Road, i.e. the Belt and Road Initiative. Upholding the philosophies of peace and cooperation, openness and inclusiveness, mutual learning, and mutual benefits, BRI deepens regional exchange and cooperation, coordinates domestic and international development, expands the space for China to implement reform and open up, and attracts the attention from countries worldwide. General Secretary Xi Jinping has repeatedly called for implementing the concept of green development in the process of Belt and Road construction, using Green as the base color of the Belt and Road. Building a green Silk Road is not only a major decision that practices the concepts of new development and that embodies China's contributions and wisdom, but also a practical measure toward realizing the 2030 Agenda for Sustainable Development together with the BRI participating countries.

To conserve the marine ecosystem, some international organizations and countries have consecutively carried out green marine operation practices, such as setting up ship emission control zones, building green ports and green fleets, strengthening emergency prevention and control of marine pollution accidents, and facilitating the pollution prevention and control from fishing ships and fishing ports. Honoring the philosophies of respecting and conserving the ocean, China stringently restricts its development activities within the environmental capacity, which constantly improves marine ecosystem health and gradually restores and optimizes marine ecosystem service. The 14th Five-Year Plan (2021-2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035 highlights the importance to actively develop blue partnership, deeply participate in the formulation and implementation of the international marine governance mechanisms and relevant rules, promote the establishment of a fair and reasonable international marine order, and facilitate the construction of the marine community of shared destiny. It values deepening the practical cooperation with maritime countries on marine environment monitoring and conservation, scientific research, and maritime search and rescue among other areas. It is also imperative to strengthen the survey and evaluation of deep-sea strategic resources and biodiversity.

According to a research by International Maritime Organization (IMO), GHG emissions of the international shipping industry occupy 3% of the global total GHG emissions. Without any emission control measures, it is estimated that the carbon emissions from international shipping will increase by 2.5 times by 2050, imposing a considerable challenge to implementing the goals in the Paris Agreement. IMO adopted the Initial Strategy on Reduction of GHG Emissions from Ships in 2018, proposing to reduce GHG emissions from shipping by 50% in 2050 compared with the amount in 2008 and endeavor to gradually realize zero-emission by the end of this century. According to the special report of Ocean as a Solution for Climate Change: Five Opportunities for Action released by the High Level Panel for a Sustainable Ocean Economy in 2019, it is likely to cut 1.8 billion tons of carbon dioxide equivalents worldwide every year by 2050 through decarbonizing shipping for passengers and goods. Many countries have started taking actions: in September 2020, the European Parliament voted to incorporate GHG emissions from ships over 5,000 gross tons into EU Emissions Trading System by January 1, 2022. Norway committed to reducing half of the shipping emissions by 2030. Fiji pledges to achieve zero-carbon shipping by 2050. Kenya announced to include the "blue carbon" ecosystem in its NDCs. Getting to Zero Coalition, established in 2019 and committed to promoting the decarbonization of the international shipping industry, has attracted the participation of more than 150 companies and organizations. It is imminent to promote the green and low-carbon development of port facilities and the shipping industry.

2. Objectives of the Research

This research will identify the opportunities and challenges in maritime connectivity and green development under the goal of carbon peaking and carbon neutralization, review port projects under the BRI and their potentials for green development, analyze the contributions of greening the national shipping industry under the BRI to realizing the goal of carbon neutralization, propose specific actions to conserve marine biodiversity, summarize the best practices in developing green ports and green shipping among BRI participating countries, and come up with policy recommendations on maritime connectivity and green and low-carbon development.

3. Connotation of Belt and Road Initiative Maritime Connectivity

Since the outbreak of the global financial crisis in 2008, the world economy has been sluggish. Trade growth has been slow and instability persists. There is an urgent need of global economy for new growth engines and new cycles. The huge demand for infrastructure and industrial development in developing countries, emerging economies included, is expected to serve as the new momentum for economic growth. It was against this backdrop that in 2013, Chinese President Xi Jinping proposed in Kazakhstan and Indonesia to build the Silk Road Economic Belt and the 21st -Century Maritime Silk Road, namely the Belt and Road Initiative. In March 2015, the Chinese government issued Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road (hereinafter referred to as Vision and Action), which proposes the top-down design framework for jointly building the Belt and Road, including objectives and vision, principles and future potential and directions (NDRC et al., 2015).

The BRI takes achieving shared growth through discussion and collaboration as its fundamental principle. The core lies in encouraging the BRI participating countries to align and coordinate development strategies, build consensus to the maximum extent, and leverage their respective comparative advantages, so as to share the achievements of the initiative and the long-term dividends. Priorities for the initiative include policy coordination, facilities connectivity, unimpeded trade, financial integration and people-to-people bond. Since being proposed, the Belt and Road Initiative has been well-received in more and more countries. Now, it has become a “Chinese solution” for participation in global openness and cooperation, improving global environmental governance system, promoting shared development and prosperity around the world and building a community of shared destiny for mankind.

In May 2017, the Belt and Road Forum for International Cooperation (BRF) was held. 29 heads of states and representatives from more than 130 countries and 70 international organizations reaffirmed the BRI core principles of consultation, contribution and shared benefits. In April 2019, the Second Belt and Road Forum for International Cooperation was successfully held. 38 heads of states, and 40 leaders of international organizations including Secretary General of the United Nations and IMF Chief attended the Leaders’ Roundtable of the 2nd BRF. Over 6,000 international guests from 150 countries and 92 international organizations attended the 2nd BRF, which provides a platform for participants to exchange opinions in-depth with each other on jointly implementing the BRI. It is widely accepted that the Belt and Road marks a road of opportunities with consensus achieved on realizing high-quality development on the Belt and Road, and fruitful outcomes have been achieved.

In the past 8 years, the Belt and Road Initiative has developed from a concept and vision to concrete actions, and entered the phase calling for full implementation and outcomes delivered. Over the past 8 years, China's direct investment in countries along the Belt and Road has reached about us $136 billion. Countries along the Belt and Road have actually invested about US $60 billion in China and set up about 27,000 enterprises in China. China has signed over US $940 billion in new contracts for projects in countries along the Belt and Road. It has achieved a turnover of nearly 640 billion US dollars (Belt and Road Portal, 2021), created hundreds of thousands of jobs and created billions of dollars of local tax revenue.

The Belt and Road Initiative aims to promote the orderly and free flow of economic elements, efficient allocation of resources and deep market integration, encourage countries along the Belt and Road to achieve economic policy coordination, carry out broader and deeper high-standard regional cooperation, and jointly create an open, inclusive and balanced framework of regional economic cooperation for the benefit of all parties.

The "Belt" refers to overland transport links or land-based route of this initiative while the "Road" is a network of maritime route. The Maritime Silk Road connects a series of strategic seaports that can serve its hinterland's trade with China and create access to European and western markets. Vision and Action outlined on jointly building Silk Road Economic Belt and 21st-Century Maritime Silk Road, which clearly points out that at sea, the Initiative will focus on jointly building smooth, secure and efficient transport routes connecting major sea ports along the Belt and Road. As the most important mode of transportation in international logistics, marine transport takes up more than 2/3 of the total transport volume of international trade. In 2018, China published a white paper entitled China's Arctic Policy and proposed to build the Polar Silk Road, which connects the port of Rotterdam in Europe and the port of Dalian in China through the Arctic. Figure 1 is a schematic diagram of Belt and Road Initiative and the Polar Silk Road (marked in red). China's maritime trade totaled 3.46 billion tons in 2020, accounting for 30% of total global maritime trade. Around 90% of China's trade by volume is carried by sea. The significance of building the Maritime Silk Road is on the rise.

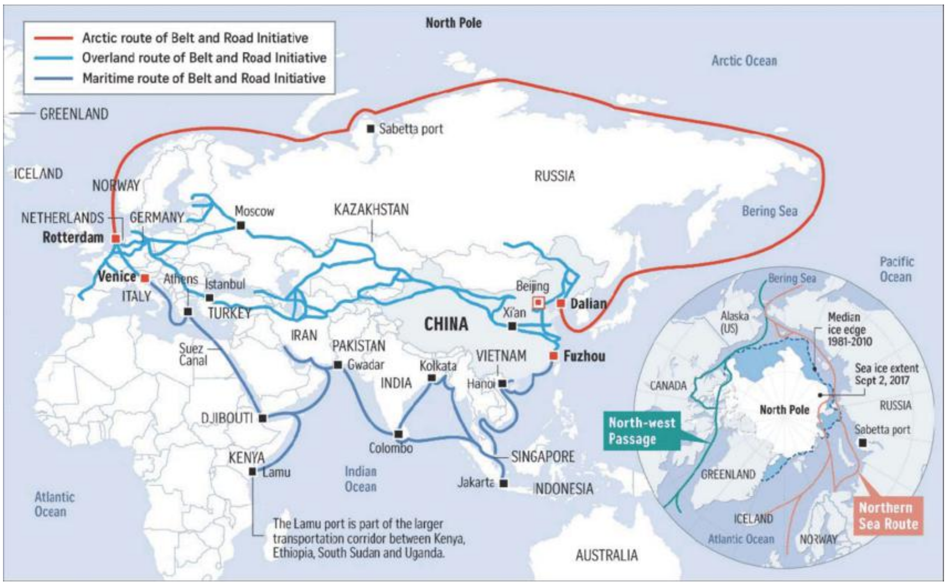

Figure 1 Schematic diagram of Belt and Road Initiative and the Polar Silk Road (Source: Straits Times, 2018)

Chapter II Green Port under the Framework of BRI

1. Concept and Evaluation System of Green Port

As a vital guarantee for the economic development of ports, the ecological environment in the port areas is so vital that once it is destroyed, the production and operation of the ports will be affected to a large extent, and even pose a threat to the survival of human beings and other species. Green port aims to achieve the coordinated development of the economic construction and the ecological environment of port cities, and emphasizes creating as many economic and social benefits as possible on the premise of keeping the ecological environment healthy.

1.1 Green Port Concept

Green port, also known as ecological port, works to protect the environment from damage on the premise of ensuring the economic benefits of a port. The key is to maintain a balance between economic and environmental benefits. In the process of determining the balance point, we should objectively and accurately grasp the relationship between economic development and environmental protection, and strive to find a sustainable development road featuring green port so as to avoid irreparable environmental problems.

The definition and theoretical basis of green port have been extensively discussed at home and abroad, which mainly involves the policies, regulations and evaluation standards of green port. In an effort to reduce the negative impact on the environment during the period of port operation, ports in California have put forward the Healthy Ports Plan. In order to promote the construction of green port, the Port of Rotterdam has implemented a sustainable port development plan and a sustainable ship plan. Shanghai Port has vigorously promoted the comprehensive improvement of the environment, expanded the scope of traditional ship pollution control, proactively boosted the construction of projects concerning shore power, and optimized the energy structure of equipment to achieve energy conservation and emission reduction. *China's Standard for Green Port Grade Evaluation* (JTS/T105-4-2020) defines green port as a port or wharf that meets the requirements of green port grade evaluation by implementing the concept of green development, proactively fulfilling legal and social responsibilities, and comprehensively adopting technical and management measures to save resources and energy, protect the environment and ecology, and deal with climate change in the process of production, operation and service.

The construction of green port comprises of such aspects as green design, green production, green procurement and green logistics. In green design, we should fully consider the impact of environmental damage and resource consumption caused by port operation, and green management and technology should be adopted in the process of port construction. In the green production, we should adopt the operation mode with little impact on the environment, protect the ecosystem in the sea area where the port is located, and reduce the discharge of pollutants in the production process whole process of port operation as much as possible. In green procurement, we use utilize green equipment with less impact on the environment, and try to use environmentally friendly, renewable and degradable green materials. In green logistics, we should apply the ideas and practical behaviors of protecting ecological environment to all steps of marine logistics.

1.2 Green Evaluation System for Ports

With the rapid development of international trade, ports serve as an important link between countries and regions. They play an increasingly important role in the comprehensive transportation system, as an indispensable hub for communication, and as a window for cities to open to the outside world. In the context of global economic integration, it is an inevitable trend to develop ports. However, port construction might leave impacts on the environment and resources, such as the development and utilization of waters, shorelines, land, particle pollution in yards and terminals, water pollution in the port area and carbon emission. Green ports are critical to coordinate economic development and ecological environment, and a science-based evaluation system of green ports would enable port companies to benchmark their construction, to identify the gap and make improvements.

1.2.1 Green Port Award System (GPAS)

The Green Port Award System (GPAS) program is a green evaluation system for ports in the APEC region developed by the APEC Port Services Network (APSN). It constitutes a critical part of APSN's ongoing efforts to promote the sustainable development of the APEC port industry as a whole.

Table 1 GPAS Indicator System

Primary Indicator		**Secondary Indicator**	
Items	%	Items	%
Commitment and Willingness	25%	Green Port Awareness and Willingness	60%
		Green Port Promotion	40%
Action and Implementation	50%	Clean Energy	15%
		Energy Saving	30%
		Environmental Protection	40%
		Green Management	15%
Efficiency and Effectiveness	25%	Energy Saving	40%
		Environmental Protection	60%

Inspired by Ecoports in Europe and Green Marine in North America, GPAS was designed as an evaluation system at the beginning by the APSN. However, it was developed differently from Ecoports and GM to be suitable for all ports in APEC region. Since 2011, the APSN has conducted two rounds of pilot programs to test the evaluation scheme in 2014 and 2015, created the Implementation Plan and established a Pool of Expert port professionals to review GPAS applications.In 2016, GPAS was officially launched. Applicants for GPAS can be any port (port authorities or port operators) that are implementing green programs to improve the environmental sustainability of their operation in the last two or more years. GPAS evaluation (certification) targeted port enterprises in Asia-Pacific region. Since its official initiative in 2016, the program has certified 38 ports from 9 economies.

The objective of GPAS is to encourage green and sustainable development in ports in Asia-Pacific region, to provide a comprehensive, science-based, reasonable and systematic roadmap to develop green port plans, and to build a platform for best practices sharing. With its implementation, the GPAS is aimed to better improve the environmental awareness, promote the sustainable development green strategy, fulfill social responsibilities, build international reputation and induce huge impacts on the international community.

1.2.2 Green Marine Environmental Program (GMEP)

In 2007, the Green Marine Environmental Program (GMEP) was founded by Green Marine (GM), a voluntary environmental certification program for the marine industry in Canada and the United States. The program encourages its participants to reduce their environmental footprint by taking concrete actions. To receive their certification, participants must benchmark their annual environmental performance through GMEP's self-evaluation guides, which would produce different levels of criteria according to the results. It is a rigorous, transparent and inclusive initiative. For each two years, with the support of a diversified network established by environmental institutions and government, GM will launch a certification to the participants, to ensure a smooth implementation of GMEP.

For participants of different types, GMEP had a different focus on certification (see Table 2). With regard to indicators shown in Table 2, GMEP would carry out self-evaluation guides for participants, to determine their performance levels (see Table 3).

Table 2 GMEP Evaluation System Indicators

Performance Indicators	Participants	
	Ship owners	Ports
Aquatic Invasive Species	√	
Cargo Residues	√	

Community Impacts		√
Dry Bulk Handling and Storage		√
Environmental Leadership		√
Solid Waste	√	
Greenhouse Gas Emissions	√	
Oily Discharge	√	
Pollutant Air Emissions NO_x	√	
Pollutant Air Emissions SO_x & PM	√	
Storm water Management		√

Table 3 Levels of GMEP Evaluation Criteria

Level	Criteria
1	Conformity with applicable regulations and adherence to GM’s percepts
2	Well planned use of a defined number of best practices
3	Incorporating best practices into an adopted management plan and quantitative anticipation of environmental effects
4	Introduction of new technologies
5	Excellence and leadership

GMEP evaluation (certification) targets prioritized North American ports. Up to October, 2013, a total of 189 members participated in the program, in which 74 passed the GM’s certification.

1.2.3 EcoPorts’ Environmental Management Standard (Ecoports)

The European Seaports Organization (ESPO), founded in 1993, involved green and low-carbon ports as its main programme, forming a green port evaluation system with European characteristics, and creating a Code of Practice that requires focus on environmental issues and responsibilities. It asked all participants to sign the Code, and established specialized committees for environmental policies and implementation. Each signed member country also drafted and executed their own environmental plans for the reference of other members. With a programme budget around 4.1 billion euros, the ESPO was born out of the European Commission, which funded 2.7 billion euros.

Self-Diagnosis Method (SDM) and Port Environmental Review System (PERS), as part of EcoPorts, were approved and recognized by ESPO and the North American Shippers Association.

As global trends of environmental protection continues to change, Ecoports' environmental priorities also shows an update. For example, in 2016, Top 10 Environmental Priorities of the Port Sector were: Air quality, Energy consumption, Noise, Relationship with the community, Garbage/Port waste, Ship waste, Port development (land), Water quality, Dust and Dredging operations. While in 2018, that became: Air quality, Energy consumption, Noise, Relationship with the community, Ship waste, Port development (land), Climate change, Water quality, Dredging operations, and Garbage/Port waste (see Table 4). Currently, ESPO website has published the 2020 Top 10 Environmental Priorities of the Port Sector.

Certification of Ecoports, which is an indicator for the green transition of global ports, is open to ports across the world. By 2018, according to the ESPO website, over 90 122 ports with high handling capacity, around the world have been certified by ESPO, including the port of Amsterdam, Netherlands; the port of London, England; the ports of Stockholm, Sweden; and Port of Oslo, Norway, etc. Besides, 26 countries have joined the Certification of Ecoports with 574 ports using SDM for self-diagnosis and 29 ports having been approved by PERS. This year, ESPO released Green Guide 2021 as its Code of Practice. The Green Guide was firstly issued in 1993 with two revisions in 2003 and 2012 respectively to keep up with the times.

Table 4 Environmental Performance of European Ports – Evaluation System (in 2018)

Items	Contents
Environmental Management Indicators	1 Certified Environmental Management System (EMS)
	2 Environmental Policy
	3 Environment Policy makes reference to ESPO's guideline documents
	4 Inventory of relevant environmental legislation
	5 Inventory of Significant Environmental Aspects (SEA)
	6 Objectives and targets for environmental improvement
	7 Environmental training programme for port employees

	8 Environmental monitoring programme
	9 Environmental responsibilities of key personnel are documented
	10 Publicly available environmental report
Environmental Monitoring Indicators	Waste, Energy consumption, Water quality, Water consumption, Noise, Air quality, Sediment quality, Carbon footprint, Marine ecosystems, Soil quality, Terrestrial habitats
Top 10 Environmental Priorities	Air quality, Energy consumption, Noise, Relationship with the community, Ship waste, Port development (land), Climate change, Water quality, Dredging operations, Garbage/Port waste
Green Services to Shipping	(1) the provision of On-shore Power Supply (OPS)
	(2) the provision of LNG bunkering facilities
	(3) the differentiation of port charges to reward greener vessels

1.2.4 China's Standard for Green Port Grade Evaluation

The *Twelfth Five-Year Plan for Transportation* pointed out that "Faced with land, shorelines and other resource constraints, China's transportation development will meet more strenuous environmental and ecological protection tasks. It will be a more urgent demand for China's green development of transport, to promote resource conservation and environmental protection, and to fasten its step in shifting to a high-efficiency, low-consumption and low-emissions economic mode." To this end, the *Overall Implementation Plan for of the Promotion of Energy Conservation and Emission Reduction of Water Transport during the Twelfth Five-Year Plan Period* put forward the requirements for establishing a long-term mechanism for green water transport, calling to draw experience of green ports certification from North America and Europe, and initiating the work of constructing China's green port evaluation system, including compiling the *Standard for Green Port Evaluation*.

Table 5 Items, Contents and Indicators of the *Standard for Green Port Grade Evaluation*

Items	Contents	Indicators
Concept	Strategy	Strategic planning
		Special fund

Action	Culture	Work plan
		Corporate culture
		Training
		Publicity
	Environmental Protection	Pollution control
		Resources utilization and ecological protection
	Energy-saving & Low-carbon	Major equipment
		Operation and process
		Auxiliary facilities
		Energy consumption
Management	System	Management institution
		Audit certification
	Institution	Target assessment
		Data monitoring
Effects	Level	Ecological and environmental protection
		Energy-saving and low-carbon

After its compilation, the *Standard for Green Port Evaluation* was released in April, 2013, and implemented in June. In April, 2015, China Ports & Harbors Association, based on the *Standard for Green Port Grade Evaluation* issued by the Ministry of Transport, launched the work of grade evaluation of China's green ports, and established the Green Port Grade Evaluation Committee. In May 2020, the Standard was revised as *Guidance for Green Port Grade Evaluation* (JTST105-4-2020), which was implemented in July, 2020. The Guidance as its core, a framework of China's green port evaluation system was set up: with 4 evaluation items, i.e. "Concept", "Action", "Management" and "Effects"; each following 1 or 2 contents, 7 in total; and 2 to 4 indicators under each content, 18 in all.

2. Status Quo and Development Trend of Green Port

As of January 30, 2021, China has signed more than 200 cooperation agreements on the joint development of the Belt and Road Initiative with 140 countries and 31 international organizations. According to incomplete statistics, by 2019, Chinese enterprises have participated in the construction of 62 overseas ports and have become the shareholders or operators of 54 overseas ports, with the number of overseas port cooperation projects having reached 116. China is playing an increasingly important role in green port construction under Belt and Road Initiative.

2.1 Overview of Major Ports in China

China's rapid economic growth has fueled the boom of port industry to reach one of the highest cargo throughputs in the world. Port of Shanghai, Port of Ningbo-Zhoushan, Port of Guangzhou, Port of Shenzhen, Port of Tangshan, Port of Tianjin, Port of Dalian, Port of Qingdao, Port of Rizhao and Port of Zhanjiang contribute to most of China's container throughput, among which Port of Ningbo-Zhoushan surpasses the others in terms of cargo throughput. By 2019, China has formed five major port clusters, namely, Bohai Rim port cluster, Yangtze River Delta port cluster, Pearl River Delta port cluster, southeast seaport cluster and southwest seaport cluster, encompassing over 150 seaports and realizing a total cargo throughput of nearly 14 billion tons. Seaports, as a vital basis of national economic development and foreign trade, as well as a major part of shipping system network, have been strongly supporting economic and trade development and improvement of people's living standards.

Table 6 Overview of the Five Port Clusters in China

No.	Port Cluster	Major Port	Leading Port
1	Bohai Rim port cluster	Include mainly Port of Dalian (Liaoning), Port of Tangshan (Hebei), Port of Qinhuangdao, Port of Tianjin, Port of Qingdao (Shandong Peninsula), Port of Rizhao (Shandong Peninsula), Port of Yantai (Shandong Peninsula) and Port of Yingkou.	Port of Dalian, Port of Tianjin, Port of Tangshan, Port of Qingdao
2	Yangtze River Delta port cluster	Centered on Port of Shanghai, Port of Ningbo-Zhoushan and Port of Lianyungang, while including Port of Wenzhou, Port of Nanjing, Port of Zhenjiang, Port of Nantong, Port of Suzhou and other sea and inland ports.	Port of Shanghai, Port of Ningbo-Zhoushan, Port of Lianyungang

3	southeast seaport cluster	Centered on Port of Xiamen and Port of Fuzhou, while including Port of Quanzhou, Port of Putian and Port of Zhangzhou, etc.	Port of Xiamen, Port of Fuzhou
4	Pearl River Delta port cluster	Centered on Port of Guangdong, Port of Shenzhen and Port of Zhuhai, while developing Port of Shanwei, Port of Huizhou, Port of Humen, Port of Maoming and Port of Yangjiang, etc.	Port of Guangdong, Port of Shenzhen, Port of Zhuhai
5	southwest seaport cluster	Centered on Port of Zhanjiang, Port of Fangcheng and Port of Haikou, while developing Port of Beihai, Port of Qinzhou, Port of Yangpu and Port of Sanya, etc.	Port of Zhanjiang, Port of Fangcheng, Port of Haikou

2.2 Overview of Ports in Major Countries along the Belt and Road

2.2.1 Overview of Ports in Major ASEAN Countries

The main ports of ASEAN countries include Port of Hai Phong, Da Nang Port, Port of Ho Chi Minh City and Saigon Port in Vietnam; Port of Manila in the Philippines; Port of Singapore; Port Klang, Penang Port and Port of Tanjung Pelepas in Malaysia; Sihanoukville Autonomous Port in Cambodia; Laem Chabang Port and Bangkok Port in Thailand; Port of Tanjung Priok and Port of Tanjung Perak in Indonesia; Port of Colombo in Sri Lanka; and Port of Yangon in Myanmar, etc. As an important economic growth engine of Vietnam, Ho Chi Minh City port cluster ranked 26th in the world in 2018.

China ranked first in terms of container throughput from 2007 to 2018 among ASEAN countries, followed by Singapore and Malaysia. In 2019, container throughput of Singapore reached 37.98 million TEUs, which was an embodiment of the high-quality facilities, efficient operation and convenient environment of the Port of Singapore and a demonstration of its capacity as an international shipping hub in Asia and the world’s largest transshipment hub. Port capacity of other ASEAN countries maintained a relatively slow growth with the throughput fluctuating between one and ten million TEUs.

2.2.2 Overview of Ports in Major South Asian Countries

Main ports in South Asia include Karachi Port and Port Qasim in Pakistan; Chittagong Port, Dhaka Port and Mongla Port in Bangladesh; Colombo Port, Hambantota Port and Port of Matara in Sri Lanka. In addition, there are 12 major seaports in India, but the infrastructure construction is relatively less-developed compared with other international ports of the same kind.

2.2.3 Overview of Ports in Major West Asian and North African Countries

Major ports in West Asia and North Africa include Port of Dubai, Port of Sharjah and Khalifa Port in the United Arab Emirates; Port of Jeddah and Port of Dammam in Saudi Arabia; Port of Muscat and Port of Sohar in Oman; Alexandria Port, Port Said Port and Port of Sokhna in Egypt. Container throughput of ports in the UAE increased from 13.18 million in 2007 to 19.17 million in 2019, which was the highest in the region for 11 consecutive years, reflecting the competitiveness of the UAE ports.

2.3 Development Level of Major Regional Ports

2.3.1 Container Throughput

Among the countries along the Belt and Road, China has maintained a high growth of container throughput since 2007, which is influenced by China's strong economic growth and significant improvement of port infrastructure. Economic development, port infrastructure optimization and increased port throughput have enhanced overall port competitiveness. In Southeast Asia, Singapore and Malaysia enjoy relatively high port throughput due to their geographical advantages of bordering the Strait of Malacca that connects the Pacific Ocean and the Indian Ocean. In South Asia, container throughput of ports in India and Sri Lanka is higher. Indian economic development drives the increase of port throughput; while foreign investment in the port and port infrastructure improvement have facilitated the rise of container throughput in Sri Lanka. In the Middle East and West Asia, higher container throughput of the United Arab Emirates, Saudi Arabia and Oman is related to port construction and development of oil trade in the three countries. Container throughput is at a low level in North African countries except for Egypt. In Western Europe, adequate port infrastructure in advanced economies including Spain, Germany, Italy, the Netherlands and the United Kingdom ensures steady container throughput.

2.3.2 Liner Shipping Efficiency Level

The LSCI (Liner Shipping Connectivity Index) of China, Malaysia and Singapore ranks among the top in the region, with China's LSCI being 151.9, the highest in 2019. To some extent, it resulted from China’s huge foreign trade volume, indicating the close relationship between China’s ports and world shipping routes. The LSCI of Myanmar, Cambodia and Brunei was at a low level from 2007 to 2019. It was affected by political environment on the one hand, whereas the small scale of foreign trade was a determining factor. In the Middle East and West Asia, LSCI of the United Arab Emirates has exceeded the others, signifying wide accessibility of UAE port network and high connectivity with ports around the globe, while Qatar’s LSCI is at the bottom. On the whole, regional port network connectivity has been elevated, but international shipping trade is limited in some countries on account of factors of international politics. The low LSCI in some regions of North Africa, East Africa and South Africa is related to poor port infrastructure and relatively small foreign trade volume. India and Sri Lanka have higher LSCI in South Asia. Australia and New Zealand are at the middle level in the region. Overall speaking, LSCI of Central and Eastern European countries is low, while Western European countries have achieved higher LSCI - Spain, France, Germany, the United Kingdom, Italy, the Netherlands and Belgium have long maintained a high and rising LSCI.

2.3.3 Port Infrastructure Efficiency Level

Singapore's port infrastructure efficiency has outshone that of other ASEAN member states, followed by Malaysia in second place and Myanmar in last. Among countries in the Middle East and West Asia, port infrastructure index of Gulf countries has been in an overall uptrend, while port infrastructure upgrade and update in Iran is hindered by decades of trade sanctions imposed by western countries. Port infrastructure in the United Arab Emirates and Bahrain are more advanced in the region. Lower and slow-growing port infrastructure index of African countries suggests that their port infrastructure is under-developed. Similar outcome can be observed in South Asia. Some Western European countries, including Spain, France, Germany, the United Kingdom, the Netherlands and Belgium, have reached high and rising LSCI. However, Italy and Greece are left behind under the impact of debt crisis in previous years.

2.4 Typical Cases and Practices of Green Ports

Some countries have integrated the concept of sustainable development into port construction and operation, which have yielded positive results, providing references for the construction of green ports around the world. With the innovation of China's green port construction concept as well as the absorption and utilization of advanced foreign practices, China has seen rapid development in green ports promotion. On 17 October, 2021, the world's first "smart zero-carbon" terminal-the intelligent container terminal in Section C of the Beijiang Port Area of Tianjin Port-was put into operation. The intelligent terminal is a major achievement of China in building world first-class smart ports and green ports and a successful case of leading the transition to smart port and green and low-carbon development with innovative models.

2.4.1 the Port of Long Beach, USA

Located in Southern California, the Port of Long Beach is the second largest port in the United States after the Port of Los Angeles. With a coastline of 40 kilometers and an area of 13 square kilometers, it has an annual import/export value of over 180 billion US dollars. There are six container ship terminals in the port, most of which have a draft depth of 50 feet. The Port of Long Beach is also one of the advocates of Green Port Concept. In January 2005, with the approval of the Port's Board of Harbor Commission, the Port of Long Beach launched "Green Port Policy" covering nearly 40 projects in 7 areas for the first time, including maintaining the high quality of harbor waters, reducing air pollution, protecting marine wildlife and habitats, alleviating traffic pressure, promoting sustainability, and increasing community engagement. The port takes active environmental protection measures and designs corresponding environmental conservation plans through investigating environmental conservation concerns. The Port of Long Beach embodies the concept of green development in all stages of terminal design, development and operation, including waste recycling; active research and development of new green technologies; use environmentally friendly materials and supplies available on the market; decrease loss in the port capability by reducing waste, conserving energy and water resources; encourage the use of new energy sources such as solar, wind and water to replace traditional energy sources.

2.4.2 the Port of Tokyo, Japan

The Port of Tokyo is committed to green port development and has formulated a series of measures. The Bureau of Port and Harbor of the Tokyo Metropolitan Government has issued green planning measures for parks in the port area, and different green spaces between parks formed a green space network from point to line and then to surface, which fully reflected reasonable and legal land use. In terms of environmental construction, the port focused on the construction of coastline scenic spots and seaside landscapes, attached importance to water-clad design and beach restoration as well as built green parks between the working terminals. Simultaneously, the port carried out land reclamation and marine environmental construction, and regarded marine parks, seaside natural landscapes, wildlife habitats, public walkways, tidal flats and other water-clad spaces as the focus of development. All measures have promoted green port construction.

2.4.3 the Sydney Harbour, Australia

Located in the eastern state of New South Wales, Australia, Sydney Harbour faces the Pacific Ocean on the east and the Parramatta River 20 kilometers to the west, surrounded by the most prosperous area of Sydney. It's owned by the government and the operator has the right of management under the administration of the harbour area, while the ownership is separated from the right of management. It's also one of the ports to implement the concept of green development at an early stage, which carried out the *Green Port Guidelines* from 7 aspects including water quality, air quality, noise control, biodiversity, waste management, dangerous goods management, environmental conservation education and training, etc. Australia has formulated comprehensive environmental conservation laws and regulations, which have had a positive binding effect on the Sydney Harbour. From 2007 to 2012, the Sydney Harbour imposed hundreds of environmental fines in accordance with the laws and handled more than a dozen cases related to port pollution. After years of efforts, the Sydney Harbour has been very successful in green port construction and has become a model for other countries.

2.4.4 the Port of Shanghai,China

In order to alleviate the conflict between environmental conservation and port construction so as to promote sustainable development, SIPG took the lead in carrying out researches on green port construction planning in China at the beginning of 2005, incorporating the green and low-carbon concept into the overall strategy of port development. The Port of Shanghai officially began building green port in 2013, and produced good results by implementing a series of energy-saving and emission-reduction measures. The diesel consumption of SIPG has seen a year-on-year decrease, while the electricity consumption has shown an upward trend, reflecting the continuous optimization of the energy structure and the gradual promotion as well as application of clean energy (such as electricity and liquefied natural gas). The main sources of air pollution in ports are emissions from fuel burning equipment, and thus reducing diesel consumption and using clean energy can effectively reduce NOx (nitrogen oxide) and SOx (sulfur oxide) emissions.

SIPG formulated the *Special Planning of Energy Conservation and Emission Reduction (2015-2020) for Building a Green, Circular and Low-Carbon Port* and the *Three-year Action Plan (2015-2017) of Green Port Development* in 2015, including 29 key supportive projects in 7 aspects. In 2016, it revised the *Summary of SIPG's Key Supportive Projects for Green Port Development (Amended)*, aiming to carry out 25 key supportive projects including RTG hybrid power transformation, automated terminal construction, LNG and other clean energy applications, shore-based power supply for ports and ships, green lighting, and information platform construction. The project completion report of the Three-Year Action Plan in 2018 showed the total energy saving was about 91,000 tons of standard coal, which replaced nearly 4,000 tons of standard oil, carbon emission reduction reaching 132,000 tons. Constructing a green port is a long-term mission and it is necessary to establish a scientific and long-term environmental management mechanism to realize the goal. As the public terminal operator of the Port of Shanghai, SIPG has promoted the development of the energy management system through the regulation establishment as well as scientific management, and incorporated environmental management into the daily operation and management process. This is of great significance to promote the coordinated development of the Port of Shanghai's operation and environment, so as to construct a green port.

2.4.5 the Port of Ningbo-Zhoushan,China

The main measures of green port construction in the port of Ningbo-Zhoushan include: starting with energy-saving equipment and facilities, logistics collection and distribution structure, fully promoting shore-based power supply, spontaneously implementing the oil-to-electricity transition for gantry cranes, and actively promoting the use of LNG fuel. At the end of the 13th Five-Year Plan, 17 sets of high-voltage shore-based power supply devices were built, and the effective coverage rate of shore-based power supply reached 60% for container ship as well as dry-bulk ship berths of 50,000 tons and above. At the end of 2020, more than 650 LNG trucks were put into operation and 8 LNG refueling stations built to use; more than 400 electric gantry cranes were put into operation, the largest scale in China. Meanwhile, it optimized and upgraded its collection and distribution structure, and vigorously developed environmentally friendly intermodal transportation methods such as road-to-railway and road-to-waterway transport. On November 19, 2020, the Port of Ningbo-Zhoushan saw annual coal transfer exceed 1 million tons by road-to-railway transport for the first time, up 276.7% on a year-over-year basis.

In Zhenhai port area of the Port of Ningbo Zhoushan, there was a chemical wastewater treatment plant built in the liquid chemical storage area and the effluent reached the second level of the China's *Integrated Wastewater Discharge Standard*. At the same time, all bulker terminals were equipped with mining and coal wastewater treatment facilities to implement domestic wastewater treatment according to local conditions. The Port adjusted the functional zones in several ways, such as transforming old berths into container and general cargo ships berths with less pollution, and transferring coal operation zone to areas far away from urban areas; setting up exhaust gas recovery pipelines in the terminals, tank farms, barrels and tank truck operation areas; actively promoting the construction of dust-proof facilities, building up wind-proof nets of more than 15,000 meters in total and so on. In June 2020, the Green Port Project in the Port of Ningbo Zhoushan was selected as an excellent case of energy conservation and emission reduction in Zhejiang Province.

2.4.6 the Port of Shenzhen,China

In order to protect Shenzhen's atmospheric environment to create a "Shenzhen Blue" sky, the Port of Shenzhen draws on excellent practices of green port construction at home and abroad to continuously enhance port energy efficiency, reduce port pollution, improve port environment, increase port competitiveness and sustainable development capabilities to promote green port construction.

The first is to take the lead in promoting the use of low-sulfur content fuel in the port. The Port of Shenzhen is the first coastal port in China that advocates the use of low-sulfur content fuel for container ships. In order to effectively carry out the *Implementation Scheme of the Domestic Emission Control Areas for Vessels in the Pearl River Delta, the Yangtze River Delta and the Bohai-Rim Area(Beijing, Tianjin and Hebei)* by the Ministry of Transport of the People' s Republic of China, Human Settlements and Environment Commission, Maritime Safety Administration and Transport Commission of Shenzhen jointly issued the *Notice on the Use of Low-Sulfur Content Fuel during Ships Berthing at Shenzhen Port* in August 2016, requiring that ships are mandatory to use fuel with sulfur content no more than 0.5% m/m when staying at berth from October 1, 2016. At present, more than 96% of the container ships berthing at Shenzhen Port use low-sulfur content fuel (not exceeding 0.1% m/m) , while ocean-going container ships have fully switched to use fuel with sulfur content not exceeding 0.5% m/m. It is estimated that compared with 2015, ships in the Emission Control Areas are expected to reduce sulfur dioxide emissions by about 600,000 tons and particulate matter by about 78,000 tons in 2019.

The second is the transformation of shore-based power supply. In March 2014, in the key task list of the *Green Port Action Plan of Guangdong Province* issued by Guangdong Province, the Port of Shenzhen became a key application for the promotion of shore-based power supply. The Port ranks first in the facilities construction and utilization in China. As of July 2018, 14 facilities in total covering 25 large berths have been built. 141 ships were connected to the facilities for 8345.5 hours. Ships from 10 international shipping companies were connected to the facilities at Shenzhen Port, using 3.2 million kilowatt-hours (kWh) of electricity. According to the evaluation of port authorities in Shenzhen , the sulfur oxide and particulate matter emissions during ship berthing have been respectively reduced by 95% and 81%. The Port completed the goal of *Five-Year Action Plan (2015-2020) for Green and Low-Carbon Port Development of Shenzhen Municipality* ahead of time, where the sulfur oxides and particulate matter emission during ship berthing will be reduced by 75% and 40% respectively compared with 2015 at the end of 2020. At the same time, the total emission reduction of various pollutants has exceeded 8,000 tons.

The third is to implement shipping subsidy policies. In 2015, Shenzhen took the lead in introducing a green shipping subsidy policy in China, investing 200 million yuan as a subsidy for green port development every year. The *Interim Measures of the Subsidy Administration for the Ports, Shore-Based Power Facilities and Marine Low-Sulfur Content Fuel in Shenzhen Municipality* and the *Implementing Regulations of Subsidies for the Ports, Shore-Based Power Supply Facilities and Marine Low-Sulfur Content Fuel* and other documents have been issued successively, providing subsidies for shore-based power supply facilities construction and use as well as voluntary conversion to low-sulfur content fuel. From March 2015 to June 2019, subsidies of 83.2911 million yuan in total for marine low-sulfur content fuel and of 75.55568 million yuan for shore-based power were granted.

The fourth is to change from oil to electricity. The main container ship terminals of the Port of Shenzhen have trialed and constructed the rubber-tyred gantry cranes (RTG) “oil to electricity” project since 2006. The energy efficiency of the gantry crane has been greatly improved while reducing exhaust gas emissions and noise by transforming engines from diesel-powered to electricity-powered. Each technically transformed gantry crane can save 80% of fuel cost and reduce 95% of exhaust gas emissions per lift. At present, there are 241 gantry cranes (207 electric and 34 hybrid ones) at the Port of Yantian, among which each hybrid gantry crane can reduce fuel consumption by 30-50% and exhaust gas emissions by more than 50% on average.

The fifth is to change from oil to gas. The oil-to-gas transformation of trailers in the port area refers to the conversion of diesel-powered trailers to ones driven by liquefied natural gas (referred to as LNG trailers). At present, diesel-powered trailers have been basically replaced with LNG trailers in the Area of the Port of Shenzhen and have cumulatively promoted more than 400 LNG trailers in Yantian, Shekou, Chiwan and other major terminals. A total of 6 mobile LNG refueling stations were built in the area of the Port of Shenzhen and put into use.

Chapter III BRI Green Shipping in the Context of Carbon Neutrality

1. Development of International Shipping Industry in the Context of Carbon Neutrality

Global maritime transport accounts for roughly 80% of the world's trade volume and 70% (UNCTA, 2017) of the world's trade by value and is responsible for about 3% of GHG emissions (IMO, 2021). In recent years, environmental pollution and carbon emission reduction in the maritime industry have received increasing attention from the international community. With the promotion of the Paris Agreement, the requirements, standards and norms of low-carbon environmental for the maritime industry have been continuously improved. The implementation of the global sulfur restriction (low-sulfur emissions reduction regulation) regulation, the setting of emission control areas (ECA) and the IMO Initial GHG strategy have put forward more stringent requirements for ship emission reductions.

Similar ambition is also observed on the customer side of the supply chain, as exemplified by companies which are also committed to carbon reduction throughout the supply chain. These companies are requiring transport companies and partners in the supply chain to carry out initiatives to reduce emissions to fulfill their green and low-carbon global social responsibilities and obligations together with cargo owners. International regulations, customer requirements and social responsibility together push green shipping forward, and the trend of green, energy-saving, low-carbon and sustainable approaches in global maritime transport is inevitable with the reality of the climate crisis.

The IMO remains committed to reducing GHG emissions from international shipping and has made reducing carbon emissions from ships a priority, but to date has not enacted any significant regulations that will drive the decarbonization of the industry. The IMO introduced the standardization Energy Efficiency Design Index (EEDI) in 2011 as the main method to control the greenhouse gas emission from newly-built ships to achieve the global maritime industry emission reduction target as soon as possible. To date the index has simply confirmed business-as-usual ship efficiency and not resulted in any significant carbon reductions. The IMO adopted an Initial GHG Strategy in 2018, making general arrangements for the maritime industry's actions to address climate change in terms of vision, emission reduction efforts, guiding principles, emission reduction measures and impacts at different stages. This is the first GHG emission-reduction strategy formulated by the global maritime industry, and it is also a consensus formed by IMO member countries under the important milestone of maritime GHG emissions reduction.

The IMO Initial GHG Strategy identifies quantitative targets and reduction measures at different phases, with the following three aspects:

1) Carbon intensity target: Reduce the CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008;

2) Total annual emissions target: Reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008.

3) Phased candidate measures (IMO, 2018):

- Short-term measures (2018-2023), improving the technical and operational energy efficiency of new ships and existing ships, research and development of alternative fuels and other efforts.

- Medium-term measures (2023-2030), alternative low-carbon and zero-carbon fuel implementation plans, strengthening technical cooperation and capacity building, etc.

- Long-term measures (after 2030), the application of zero-carbon fuels, and encourage the widespread application of feasible emission reduction mechanisms.

The IMO Initial GHG Strategy will improve the short-term measures and legal framework in 2023, which will implement mandatory measures for existing ships and put forward the final strategy. The relevant requirements, rules and technological development changes will determine the future direction of the maritime industry to achieve carbon-neutral operations. This will bring significant impacts to the formulation of relevant policies and technological development in major maritime countries including China. The phased targets and measures for energy saving and emission reduction in the maritime industry will also be adjusted, and relevant new regulations and new technical standards will become important factors affecting the future green and low-carbon development of the maritime industry. Subsequently, the new development opportunities and challenges for ship technology, ship building and the maritime industry will also come.

However, IMO's new measures on GHG mitigation are widely questioned by the shipping industry. There are concerns that these measures may slow down the scrapping of inefficient older ships and make it difficult to accelerate the renewal of the global fleet.

Box 1: Getting to Zero Coalition

In 2018, IMO adopted initial GHG strategy, which identifies the targets of reducing the CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008; and reducing the total annual GHG emissions by at least 50% by 2050 compared to 2008. Following the release of the IMO targets, Friends of Ocean Action, the World Economic Forum and the Global Maritime Forum formed the "Getting to Zero Coalition" in 2019. Currently, the Coalition comprises more than 160 organizations in the maritime, energy, infrastructure and finance-related sectors, and is supported by numerous governmental and intergovernmental organizations. The Coalition aims to achieve operation of zero-emission ships on deep sea trade routes by 2030, with infrastructure supported by zero-carbon energy sources across the production, distribution and storage chain. The Coalition is established complying with this objective and core principles, and achieving this common objective requires the cooperation and commitment of all stakeholders.

The Coalition focuses on four core components of the Agenda for Sustainable Shipping, highlighting concerted efforts of members from public and private sectors towards zero emissions from shipping by 2050:

1. Fuel technology: narrow the options of fuel technology, and scale up new fuels based on safety implications, guidelines and regulations.
2. Incentivizing first movers: explore policies, demand drivers, and funding mechanisms to incentivize first mover investment and reduce their risks.
3. Closing the competitiveness gap: explore policy making, market and non-market related measures to close the competitiveness gap between conventional and zero-emission fuels and ships.
4. Opportunities for global export of zero-emission fuels: assessment of possible country partners.

Source: World Economic Forum

2. Green Shipping in the Context of Carbon Neutrality

2.1 Definition of Green Shipping

The concept of “green shipping” originated from Green Shipping Practice in 2004. Green Shipping Practice refers to that shipping companies use alternative ship facilities to reduce the environmental damage arising from maritime cargo by calculating the carbon emissions along shipping routes in their shipping practices. The concept has evolved from environmental management, to coordinated development of shipping economy and environment, and finally to a strategic objective of shipping development by integrating the principle of sustainable development for intergenerational equity. It is clearly put forward in the Guiding Opinions on Promoting Green Shipping Development in Yangtze River Economic Belt issued by the Ministry of Transport of China in 2017 that, “ Strive to scale up green development approaches, and promote the green, circular and low-carbon shipping development by focusing on green waterways, green ports, green ships and green transport modes”.

2.2 Opportunities for Green Shipping

Shipping contributes to over 80% of the global freight volume, while its total carbon emissions only accounts for 6.1% of the transport sector. In terms of energy consumption per unit, shipping is still the greenest and most economical mode of transport. In the context of energy-saving and emission reduction, green shipping also presents enormous business opportunities, specifically in the following aspects:

Business opportunities for technological innovation. For a long time, due to limitations of low-speed ICE manufacturing technology, China has encountered difficulty in making major breakthroughs in ship power technology. Nowadays, the development and application of new energy in the field of shipping, presents an opportunity to “change lanes and overtake”. For example, the relatively mature land-based technologies such as fuel cells, solar energy, and wind energy can be used to shipping, leading the new trend of energy upgrading.

Business opportunities for new shipping infrastructure. According to estimates, there will be nearly $4 trillion of annual investment opportunities around “carbon peaking and carbon neutrality” in the future. A significant proportion investment will definitely flow into the energy transformation of the shipping industry, fostering a large number of “new infrastructure” globally, giving rise to various new business models, and presenting enormous business opportunities.

Business opportunities for energy efficiency improvement. In the past, the shipping industry emphasized cost competition, service competition and safety competition, while the carbon emission reduction capacity will be added into the core competitiveness of shipping companies in the future. Indicators and requirements such as Energy Efficiency Existing Ship Index (EEXI), Carbon Intensity Index (CII), and Ship Energy Efficiency Management Plan (SEEMP), etc. arises. Improved energy efficiency creates more business opportunities.

Opportunities for rules discourse. Because of its international nature, green shipping is not a single issue of one country. China should take advantage of this issue to enhance its leadership in international maritime rule-making, shift from "participant" to "leader" of rules, and further improve the voice of Chinese shipping practitioners in global marine environmental governance.

As an old saying quoted by Chinese President Xi Jinping at Leaders Summit on Climate, "When people pull together, nothing is too heavy to be lifted." As a global industry, the shipping industry requires a global solution to meet the challenges of carbon emission reduction, which relies on the exchange and cooperation of the global shipping industry chain. In the meantime, in the face of the opportunities brought by green shipping, shipping practitioners shall take the initiative to act with a pioneering and innovative spirit, and contribute more wisdom and strength to the building of "a community of life for man and nature".

2.3 Challenges Facing Green Shipping

China put forward the "Belt and Road" Initiative in 2013, with the development of BRI, the trade among BRI countries has been growing steadily. Given the complex mix of trade commodities, the drivers of ship emissions may vary greatly. In the context of carbon emission reduction, it is very essential to study and develop green shipping in BRI countries, and explore the optimal ship emission scheme among BRI countries while meeting trade needs.

In 2021, the climate issue once again became a hot topic around the world. China has reaffirmed its carbon peak and carbon neutrality targets, and carbon emission reduction is becoming a goal and trend in global economic development. Achieving these targets will inevitably increase the initial investment and operating costs of ships. Therefore, policy-makers are required to develop policies that are favorable to first movers in terms of taxation, carbon emissions, financing, insurance, market segmentation and access, so that first movers can take the first step, advance technology, and significantly reduce costs in all aspects of electricity and low-emission fuel production and supply, thus achieving these targets in a sustainable manner. Current challenges arise from the following:

First, **new energy technology is in urgent need of breakthroughs**. Ships have a life cycle of up to 25 years, while the existing new energy technologies for ships such as natural gas, fuel cells, ammonia and hydrogen are not mature enough. Solar, wind and other zero-carbon energy power units still have low power and other problems. It is urgent for the shipping industry to achieve technological breakthroughs within the window available.

Second, **global operational security system needs to be upgraded**. Ships require a sound energy security system for global navigation, but the existing security systems are built on traditional energy sources. The deployment of new energy sources will necessarily require a complete overhaul of existing port and maritime security facilities. In addition, there is a need to ensure the smooth refueling of various low-/zero-carbon fuels globally, as well as the continuous supply of shore-based charging equipment. All of these pose rigorous challenges.

Third, **cost increases**. The policy implementation of environmental responsibility for energy saving and emission reduction could mean intensive technological transformation and high cost inputs. The EU's unilateral action plan to include the shipping industry in the EU Emission trading system (ETS), and the US's intention to impose “Carbon Border Adjustment Mechanism” or “CBAM”, will certainly increase shipping costs. If all carbon emission reduction responsibilities are imposed on shipping companies indiscriminately, then shipping companies would be overwhelmed.

Fourth, **rule changes**. Carbon emission reduction of the shipping industry is not only a matter of economic responsibility, but also involves legal obligations. Given its long industry chain, many players in the chain should be responsible for compliance. Countries should early agree on how to allocate relevant compliance responsibilities in a reasonable and prudent manner, how to improve compensation and contribution mechanisms, and how to deal with non-compliance issues.

In general, the pathway of carbon emission reduction for ships should be based on national conditions, with emphasis on national policy directions and energy security strategies. The *Outline of the 14th Five-Year Plan (2021-2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035* clearly proposes to “expand the brand influence of the 'Silk Road Shipping' ”. It has given rise to a number of measures, such as establishing a national center of ship energy consumption, a monitoring, reporting and verification (MRV) system for shipping GHG emission reduction, atmospheric emission inventory and GHGs emission inventory for ships, and improving the data collection mechanism on ship energy consumption. Besides, China has been actively involved in global governance on emission reduction in the shipping industry.

Box 2: Driving forces of China-US maritime trade

GHGs emission from shipping associate with the types of import/export commodities and ships that transport these commodities. Analyzing the intrinsic drivers of ship emissions among trading countries by using ship AIS data and inter-country trade data could attempt to reduce ship emissions by optimizing the energy efficiency of inefficient commodity sectors or adjusting the commodity structure to explore the potential of shipping emission reduction, then governments could develop a targeted approach to help reduce emissions from ships.

A study was conducted in 2016, to analyze emissions associated with trade between China and the U.S using ship AIS data (Liu, H. et al, 2019). It is estimated that ships travelling from China to the U.S. emitted 188,000 tons of sulfur dioxide and 13,76 Mtons of carbon dioxide, while the ships travelling from the U.S. to China emitted 133,000 tons of sulfur dioxide and 9,2 Mtons of carbon dioxide. Using ship-cargo matching techniques, the drivers of ship emissions can be traced back to the commodity sector, as shown in the figure 2 below (Liu, H. et al., 2019)

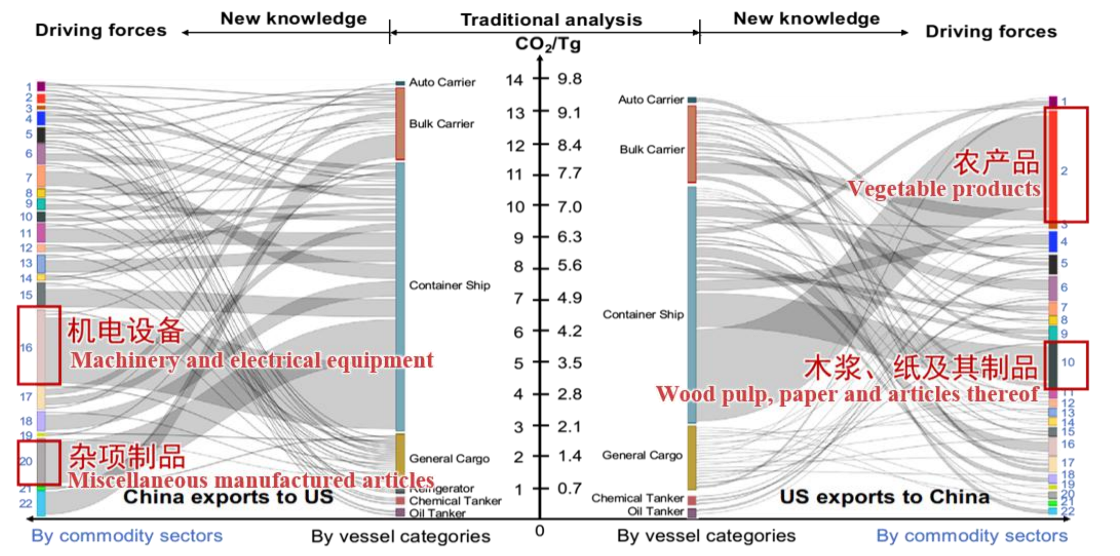

Figure 2 Driving forces of China-US maritime trade

It can be seen that the major contributors to maritime emissions of US-China and China US trades are significantly different. Electromechanical equipment and miscellaneous manufactured goods are the main drivers of shipping emissions from Chinese exports into the US. In contrast, US exports to China is dominated by agricultural products and waste. Meanwhile different commodity categories show wide spectrum of energy efficiency. Take category 10 commodities as an example (Liu, H. et al, 2019), they are mainly waste paper, waste plastics and waste metals exported from the U.S. to China. The emission from this category accounted for 15.2% of total U.S.-China trade transport emissions, but only 3.2% of total U.S. export to China. Similarly, category II commodities, which account for 12.4 percent of the value of trade from the United States to China emits more than 40 percent of total emissions from U.S. exports to China. These examples indicate that energy intensity of commodity trade for both categories is low and their carbon intensity is high.

Such insights from the data, could provide an input to design of a policy measure such as carbon pricing that aims to internalize carbon emissions from import and export activities among BRI countries. Additional costs of GHG emission along with mechanisms to trade carbon credit could, in the long-term, provide the necessary incentive to adjust trade structure globally. Such policy measure may cause countries to import/export from closer countries and incentivize ship operators to use more energy-efficient ships or routes.

3. Maritime CO2 Emissions from BRI Countries and Shipping Sector in NDCs

3.1 Maritime CO2 emissions from BRI countries

In this project, we focus on international maritime transport within BRI. The geographic scope is dynamic as countries join China's BRI. We surveyed the available literature and identified the following 23 countries and Iraq as part of the 21st century maritime silk road (MSR).

Table 7 The 23 countries in the 21st Century MSR Source: (imsilkroad, 2020)

Participant Countries in the MSR			
Brunei	Italy	Pakistan	Thailand
Cambodia	Japan	Philippines	Turkey
Egypt	Kenya	Saudi Arabia	United Arab Emirates
Greece	Kuwait	Singapore	Vietnam
India	Malaysia	Sri Lanka	Republic of Korea
Indonesia	Myanmar	Tanzania	(Iraq)[1]

It is important to note that this report shall refer to CO_2 emissions due to constraints with availability of research that references GHG emissions, except in instances of methane and LNG. To tackle the climate crisis, all GHG emission must be addressed from shipping.

Carbon emissions from international trade between BRI countries along the MSR are projected to reach approximately 41 million tons by 2050, in a baseline scenario without any additional policy measures. This would represent a 154% growth of emissions by 2050 compared to 2020

3). The baseline scenario incorporates the impact of existing international regulations, including on the energy efficiency of ships (IMO's EEDI regulation).

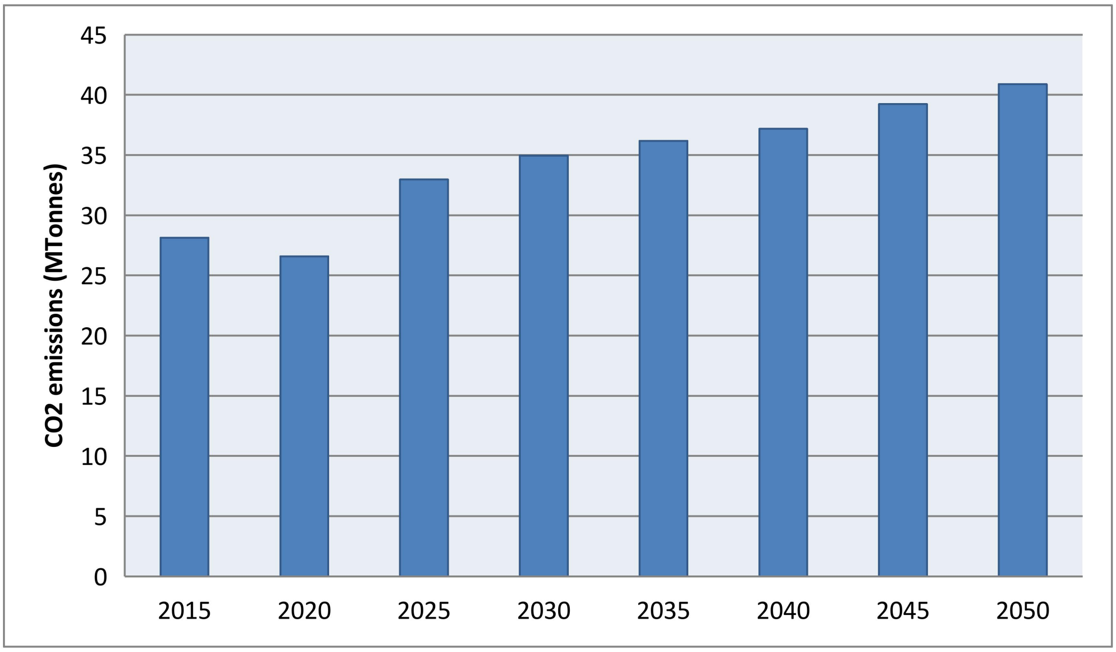

Figure 3 Different projections for shipping's CO2 emissions to 2050 along the MSR

These projections are based on the Equitable Maritime Consulting's (EMC) International Freight Transport and Emission Model (ITEM), designed to estimate freight transport demand and emissions for 19 commodities in all transport modes, using actual routes and related real distances, converting trade in value into freight volumes in ton-kilometers (Halim et al., 2018). The model is deployed to assess CO_2 emissions among 23 BRI countries that are part of the 21st century MSR as listed in. The model uses trade projections from the OECD trade model (Chateau et al. 2014), a Spatial Computable General Equilibrium Model, which is able to account for the dynamic evolution of international trade, both in terms of spatial patterns and commodity composition. The carbon emission projections are the result of multiplication of these transport activity data with energy and carbon intensity data per different ship types in the business-as-usual scenario (scenario 2), as published by UMAS (Smith et al., 2016). A geographical representation of shipping emissions in 2050 shows that a large share of carbon emissions in the baseline scenario is generated along China-Europe trade lanes.

Figure 4 Visualization of CO2 emission across the 23 countries along the Maritime Silk Route in 2050

4)The rise of international trade is the main driver for the growth of international shipping emissions along the MSR. Although global trade saw a 9.2% decline in 2020 due to the global COVID-19 pandemic, a strong rebound of up to 7.2% is expected in 2021 (ITF, 2021)

Nevertheless, a slower growth rate for freight transport activities is projected as an outlook for international freight in ITF's most recent report (ITF, 2021). Specifically, the compound annual growth rate (CAGR) of demand for freight transport between 2019-2050 will see a decline to 2.7% compared to the 3.4% pre-pandemic growth rate between 2009-2019. This downward adjustment from the previously available projections is in line with IMF's projection on the recovery of trade and economic activities post pandemic (IMF, 2020). The driving factors for this downward trend include:

- Slower GDP growth of countries globally pre-pandemic
- Global supply chain disruptions due to COVID-19 which affected international trade volume negatively.
- Intra-regionalization of trade in which countries begin to import from countries with higher proximity instead of relying on long-distance trade (also called near-shoring).

Taking into account these trends, OECD projects a decline in the compound annual GDP growth rate (CAGR) from 3.3% to 2.6% for the 2015-2050 period (OECD, 2020).

Certain macro-economic trends in global GDP growth patterns remain the same. The GDP growth of emerging and developing economies, such as BRI member countries, is projected to outpace those of OECD countries. This trend would result in a shift of global economic weight to non-OECD countries and a restructuring of global trade patterns. By 2035, China and India could dominate global trade with 23% of global export flows. The share of export values from Europe might be reduced to 26% of the global export flows in 2035, compared to 33% in 2015.

Demand for international maritime transport until 2050

Our maritime transport demand projection adopts similar underlying assumptions on global trade and GDP growth as laid-out by ITF (ITF, 2021). The resulting projection for international freight transport is aligned with that of ITF projection (ITF, 2021), in which international shipping demand is expected to grow around 255% compared to the 2015 level.5). The more-than-doubling of international shipping demand in 2050, although significantly less than previously projected, still reflects a substantial contribution to GHG emissions.

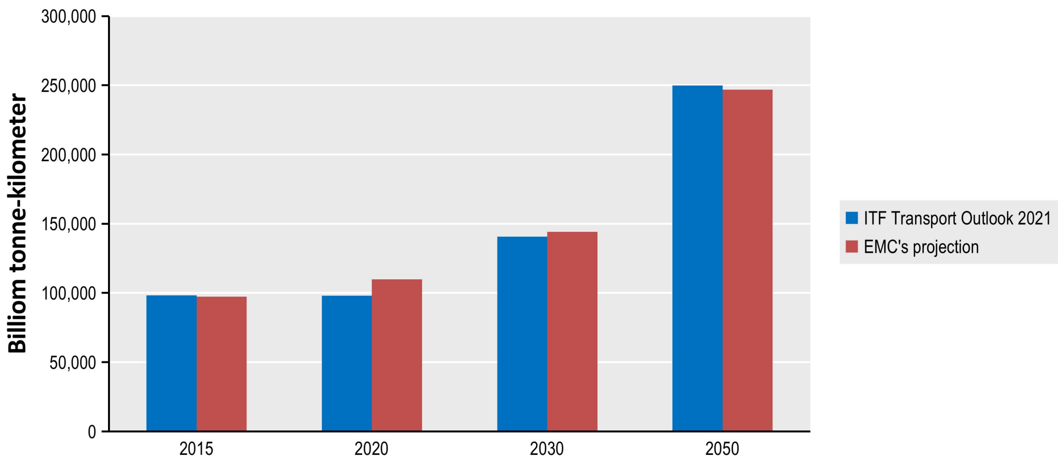

Figure 5 EMC and ITF projection for international maritime transport Source: ITF, 2021

CO_2 emissions from international shipping until 2050

Our projection of baseline emissions for international shipping is aligned with the outcomes of the BAU scenarios presented in the Fourth IMOGHG Study. In the IMO scenarios, carbon emissions are projected to increase from 1000 Mt in 2018 to 1500 Mt in 2050, or equivalent to a 130% increase compared to a 2008 level at 1135 Mt. Our carbon emission projection is similar to the SSP2_RCP2.6_L.6), which describes the emissions from shipping compliant to the 2 degrees Paris Agreement target. A noticeable difference between EMC's and IMO BAU SSP2_RCP2.6_L is in 2020 emission levels, where EMC projection captures the decline in maritime transport demand – resulting in a considerably lower emission level.

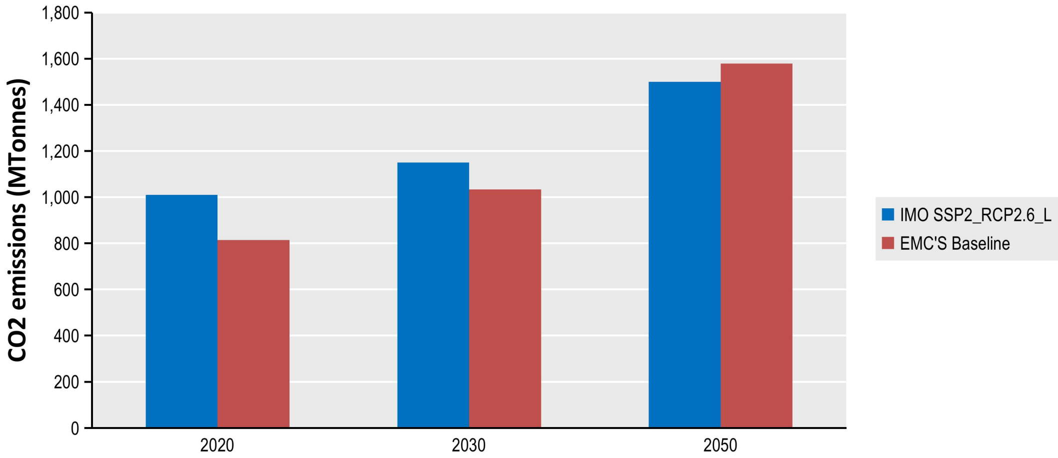

Figure 6 EMC and IMO's Baseline CO2 emissions

The IMO shipping projection scenarios are based on so-called Representative Concentration Pathways (RCPs) for future demand of coal and oil transport and Shared Socioeconomic Pathways (SSPs) for future economic growth (i.e. GDP and population) developed by Riahi et al. (2017). Based on these transport demand classifications, our trade projection shares similar characteristics with SSP 2 and RCP 2.6. In SSP 2 scenario, there is a moderate growth of transport demand for all commodities due to moderate growth in GDP and population of countries. RCP 2.6 scenario depicts a world with a moderate growth on the transport demand for non-coal bulk and dry cargo, while there is a decline in the global energy consumption from coal and oil products to limit the global temperature increase to below 2 degrees Celsius.

Uncertainties in 2050 emission projections

Despite the various factors that we have taken into account, there are inherent uncertainties in how future transport demand will evolve. All projections of shipping emissions are based on certain underlying transport demand assumptions or low-carbon shipping technologies that may or may not materialize. Uncertain factors, among others, could include geopolitical tensions that lead to reduced trade between certain countries, successful regional economic integrations and trade agreements between countries such as ASEAN, successful implementation of the MSR or successful agreement on global regulatory measures that stimulate the adoption of zero-emission shipping technologies.

3.2 Shipping Sector in the Nationally Determined Contribution (NDC) of BRI Countries

The NDC represents a country's national effort to reduce GHG emissions from each of its economic sectors to attain the goals of the Paris Agreement. The NDCs typically also represent the commitments and promises of a national government to reach their decarbonization targets, which should be consistently reflected in international policy negotiation processes – such as the one that the IMO facilitates. Currently, shipping is not specifically mentioned in the Paris Agreement, the IMO is responsible for formulating and adopting a decarbonization strategy for the sector that is aligned with Paris Agreement goals. Although shipping is not specifically mentioned in the Paris Agreement, national governments play a major role in directing and supporting the decarbonization of the shipping industry both domestically and internationally.

To understand the latest policy measures and commitment of BRI countries for international shipping, this report conducted desk research on the NDC documents submitted by 23 BRI countries along the MSR. These 23 countries are selected because of their direct participation in the MSR as explained in section 1. Table 8 provides an overview of the inclusion of shipping sector in the NDC's of 23 BRI countries.

Table 8 MSR Countries and summary of involvement of shipping sector in their NDC

No	Country[1]	Shipping sector in NDC[2]	Contents
1	Brunei	No	-
2	Cambodia	No	-
3	Egypt	NA	NA
4	India	Yes	Fuel efficiency in Coastal shipping and inland waterways
5	Indonesia	No	
6	Iraq	No	-
7	Italy		-
8	Japan	Yes	Modal shift, energy saving ships, eco-friendly ships
9	Kenya	No	
10	Republic of Korea	Yes	Modal shift and use of LNG ships
11	Kuwait	No	
12	Malaysia	No	-
13	Myanmar	No	-
14	Pakistan	No	-

15	Philippines	No	-
16	Saudi Arabia	No	-
17	Singapore	No	-
18	Sri Lanka	Yes	NDC 12, reduce emissions; introduce energy efficiency and improve fuel quality
19	Tanzania	Yes	To improve modal share of maritime transport[3]
20	Thailand	No	
21	Turkey	NA	- NA
22	UAE	No	
23	Viet Nam	No	-

1. EU countries excluded; overarching EU regulations may apply to member states
2. Refers to direct mentioning of maritime/ shipping sector. Does not include references to transport in general
3. There is no clear reference to movement of people or freight
4. NA = Document was not available/ or not accessible

Thus far, only 5 BRI countries have included the shipping sector in their NDC. The shipping sector needs a clear vision and strong national government leadership to provide certainty and start rapid decarbonization.

4. Policy Review: Green Shipping Landscape in Typical BRI Countries and China

The shipping industry is the foundation of global economic and social development. We selected six BRI countries Indonesia, Singapore, Sri Lanka, UAE, Italy and Greece, as well as China and analyzed the current landscape, policy status for shipping and the involvement of shipping sector in their NDC in each of the selected countries to give feasible policy recommendations at a country and regional level. The selection considered a geographically-balanced representation of BRI countries included in the case studies and was based on further criteria such as the presence of China's strategic agreement and cooperation with the countries, potential for growth in their bilateral trade with China and data availability. All seven case study countries are IMO members that ratified MARPOL Annex VI, aiming to support decarbonization of maritime transport. The implementation of green shipping initiatives indicates the willingness of countries to decarbonize the shipping industry through national government regulations.

4.1 Policies on Shipping in Each Case Study Country

4.1.1 Indonesia

To date, there are three main regulations that govern the greening of Indonesia's maritime sector:

a) Ministry of Transport Regulation No. 29 (PM No.29) of 2014: Obliges ships sailing in Indonesia's sea territory to comply to international standards regarding energy efficiency and encourages the use of low-sulphur fuels.

b) Regulation of the Minister of Energy and Mineral Resources (MEMR) No. 12 of 2015: The incorporation of biodiesel as much as 30% of the total diesel fuel (known as B30) is mandatory for the transportation sector starting in 2020.

c) Presidential Regulation No. 38 of 2019: Aims to reduce emissions from the shipping sector by increasing the uptake of gas to replace heavy fuel oil for fishing boats.

Indonesia has started the implementation of a GHG Monitoring Reporting Verification (MRV) System, with the aim to reduce GHG emissions, as defined in the NDCs. This is a collaboration between several national ministries and agencies to monitor and verify national GHG emissions. Indonesia also supports green shipping initiatives that are formed under multilateral agreements and cooperation, including the ASEAN Green Ship Strategy and MEPSEAS (Marine Environment Protection of the South-East Asian Seas).

Indonesia could harness its great renewable energy potential to produce zero-carbon fuels for shipping. Blessed with diverse geographical landscapes, as well as being on the equatorial line, Indonesia has very high potential to create renewable energy from solar photovoltaic power (IRENA, 2017). However, Indonesia still struggles to grow the share of renewable energies in supplying its domestic energy demand. The country lacks clear and strong renewable energy policies and has overly-complicated regulations for investments that can support clean energy development. Although Indonesia has great potential to be a supplier of zero-carbon fuels such as green hydrogen and green ammonia, government policy measures would need to remove these barriers.

4.1.2 Singapore

Singapore has introduced four major green shipping initiatives, which mainly focus on raising awareness and encouraging the use of low-carbon fuels by granting a reduction of annual tonnage tax and vessel registration fees.

The Green Shipping Programme encourages a reduction in GHG emissions of all Singapore flagged ships to quality for rebate in annual tax and registration fees (Maritime and Port Authority, 2021b). Under the Green Port Programme vessels calling into Port of Singapore are encouraged to adopt LNG and exceed Energy Efficiency Index requirements of IMO. Adhering to these solutions also provides financial concessions in terms of reduced port dues and taxes. The Green Awareness Programme and the Green Energy and Technology Programme aim to encourage local maritime companies to adopt carbon reporting and carbon pricing and to develop greener technologies for shipping.

The Green Awareness Programme and the Green Energy and Technology Programme aim to encourage local maritime companies to adopt carbon reporting and carbon pricing and to develop greener technologies for shipping. Furthermore, the Maritime and Port Authority of Singapore is developing the Maritime Singapore Decarbonization Blue Print 2050 (Maritime and Port Authority, 2021a) to create decarbonization strategies to reduce maritime emissions and GHG emissions specific to international shipping. The strategies include the electrification of ports and terminals with solar photovoltaic power and the increasing use of alternative fuels such as hydrogen and ammonia.

4.1.3 Sri Lanka

Sri Lanka, a developing country with a relatively small economy, is currently at the beginning stage of developing green shipping initiatives. Before developing concrete and tangible policies, the Port Authority aims to develop baseline numbers, which will be reported in the Port Master Plans (MTBS, 2020). The government also established an active monitoring program of sulfur and GHG emissions (UN ESCAP, 2021).

Sri Lanka’s potential to develop low and zero-carbon fuels is relatively limited, as its national energy grid is in urgent need of modernization and will not be able to provide enough renewable energy to also satisfy demand from shipping (Sri Lanka Energy Authority, 2021). Rather, due to its strategic geographical location, it could be a bunkering hub for zero-carbon fuels in the region.

4.1.4 United Arab Emirates (UAE)

The UAE aims to cut carbon emissions by 70% in 2050 by transitioning away from fossil fuels towards cleaner energy (Ministry of Energy and Infrastructure, UAE, 2021). The National Energy Strategy 2050 does not explicitly mention shipping, but maritime transport is considered as a key demand sector for future energy consumption. Although policies that regulate the shipping industry are lacking at the national level, many individual emirates are currently implementing initiatives to adopt a greener maritime trade across the UAE and the Gulf region. The main goal is to store, consume and even produce alternative fuels such as hydrogen and ammonia.

The UAE is well equipped for a shift toward renewable energy sources, especially as high amounts of sunlight have the potential to power a substantial solar fleet. Hydrogen produced in the UAE could predominantly be used for export rather than consumption, as solar power alone can more than satisfy domestic demand (Watson Farley & Williams, 2021).

4.1.5 Italy

Although Italy does not have a specific maritime policy regarding environmental governance, various fragmented national regulations do exist. National green shipping initiatives are guided by the Integrated National Energy and Climate Plan (NECP), which outlines the country’s strategies to achieve the goals of the Paris Climate Agreement and the New Green Deal. While the utilization of hydrogen is not yet economically viable, the plan envisions hydrogen will become a key decarbonization strategy for transport, including the maritime sector. As enacted in the legislative Decree No 257, Italy's main objective is to build bunkering and storage facilities in ports, and to encourage the use of LNG vessels by establishing beneficial port tariffs and removing tax barriers (NECP, 2019). Furthermore, the provision of electric power supply at all ports for ships, such as onshore power supply (OPS) are set goals.

Italy faces a challenge to scale up its renewable energy sources (Watson Farley & Williams, 2021), which makes it difficult for Italy to become a producer of synthetic fuel such as green hydrogen or green ammonia. Currently, international regulation and incentive schemes to adopt waterborne hydrogen-fueled transport are rather weak, which hinders progress in the development of hydrogen as low-carbon fuel for the shipping industry (EUKI, 2019).

4.1.6 Greece

Greece's National Energy and Climate Plan (NECP) from 2019 outlines the country's goal to achieve a sharp reduction of greenhouse gas emissions by 2030 (56% reduction compared to emissions in 2005). The plan delineates several policy measures to achieve these goals, including a section on the shipping sector. The government aims to retrofit its major ports to become storage facilities for LNG, with the port of Piraeus being the main center for the supply of LNG to ships. Incentives for converting or replacing ships to exclusively operate on LNG will be provided through financial/tax support and docking costs for these ships will be reduced. While the NECP and the recently adopted Decree 64/2019 promote the use of LNG as primary fuel for ships, the Ministry of Environment and Energy has announced the launch of a committee which will oversee and develop a national strategy for the development of hydrogen and other gases from renewable energy sources (Watson Farley & Williams, 2021). However, no concrete hydrogen policies and measures are provided, nor does the NECP put forward a clear hydrogen target.

Greece has a promising potential to produce green ammonia/hydrogen for shipping due to its favorable geographical location and weather conditions (Englert, Dominik et al., 2021). The country's main RES potential lies in offshore/onshore wind farms and solar power (Dianellou et al., 2021). However, Greece's mainland power system currently lacks connections to the autonomous power systems of its many islands, which hinders the full utilization of renewable energy production possibilities. The electrification of ships and port operations require stable and efficient energy supply, which is why local electricity networks need to be strengthened to be able to cope with peak times in ports.

4.1.7 China

China has become an influential shipping power in the world and is steadily starting a new journey to accelerate the building of a strong transportation and maritime power. China has initiated a green shipping system by adopting energy-saving and environmentally-friendly ship equipment, economical use of shipping resources and advanced and efficient transport organization. The country has formed a good situation of scientific, ecological and intensive development in the water-borne transport industry, with significant progress in key areas covering green ports, green shipping and green operation model.

The Ministry of Transport has introduced a series of policies to guide the ship and maritime industry to actively pursue technology development and construction of green ships. In 2017, the Ministry of Science and Technology, together with the Ministry of Transport, issued the 13th Five-Year special Plan for Science and Technology Innovation in Transportation, listing advanced propulsion technology for ships and green ship design and optimization technology as key science and technology development directions. In August 2020, the Ministry of Transport issued the "Guidance on Promoting the Construction of New Infrastructure in Transportation."

In terms of technology research and development, Chinese enterprises and scientific research institutions also regard green low-carbon, energy-saving and high-efficiency technologies as important factors for ship research and development. Construction achievements have been made in the research, development and application of energy-saving ship models, energy-saving equipment, emission reduction technologies (such as desulfurization and denitrification), energy-saving materials, alternative energy sources and ship construction processes. Some of the technologies are already at the international advanced level.

At the present stage, China's green shipping development meets the environmental protection requirements of the IMO, but there are still great challenges for the higher green and low-carbon requirements of the maritime industry in the future. The period of 2020-2030 is key for the application of green ship technologies and technology research and development. Research on alternative energy technologies is particularly important to achieve net-zero by 2050 in the shipping industry. China has started to research zero-carbon energy applications, including hydrogen, ammonia, methanol, and lithium. Currently, research regarding alternative fuels should focus issues of safety, storage, accessibility and economy.

4.2 Policy Recommendations of the Case Study Countries

Based on the analysis of the seven case studies that are part of the MSR, we develop country-specific recommendations to accelerate green shipping development. Table 9 provides a summary of policy recommendations for each country, taking into account their current shipping policies, strengths and weaknesses, and future emissions from international trade.

Table 9 Summary of NDC, green shipping initiatives and recommendations of the countries in the seven case studies

Country	**NDC from maritime Sector**	**Recommendations**
China	No specific target on maritime sector.	• Strengthen research and application of zero-carbon energy sources such as hydrogen and ammonia. • Accelerate domestic energy transformation, increase the proportion of clean energy, and achieve low carbon throughout the life cycle of ports

		and ships. • Strengthen technological innovation in green ship design and optimization. • Establish a green shipping cooperation platform in Belt and Road countries. • Carry out technical cooperation and research on zero-carbon energy in Belt and Road countries, carry out ship energy cooperation with MSR countries and major maritime trading countries, and jointly build zero-carbon fuel supporting infrastructure. • Explore including the shipping industry in China's carbon emission trading market and specify carbon emission reduction targets. • In addition to tax relief for ships, provide incentives for ships using new zero-carbon fuels such as ammonia or hydrogen, and the construction of new energy ships could be encouraged. • Assess the long-term costs, benefits and risks of various alternative fuels or new energy sources and develop a long-term ship energy development strategy.
Indonesia	No specific target on maritime sector.	• Establish a dedicated funding program supported by a carbon fee on shipping. • Explore the high potential of renewable energies. • Pursue Indonesia-China MSR agreements for investments in zero-carbon bunkering infrastructure.
Singapore	No specific target on maritime sector.	• Pursue economic cooperation with neighboring countries for generating energy from renewable sources. • Include a commitment to support the development of zero-emission fuel supply chain and bunkering infrastructure in the NDC and NAP. • Focus on innovation in technology and alternative fuel. • Attract investments for zero-emission bunkering facilities at major ports.
Sri Lanka	NDC-12 addresses reduction of GHG emissions from marine sector.	• Monitor and establish ship emission databases. • Collaborate and invite partners to develop sustainable long term maritime solutions for port activities and shipping. • Participate in capacity development programmes.

		• Establish funding program for developing zero-emission bunkering infrastructure.
UAE	No specific target on maritime sector.	• Leverage UAE's solar energy potential to decarbonize port activities. • Play a pivotal role in the gulf region in green ammonia production and alternative fuels. • Explore possibilities of using current pipeline infrastructure to store and transport zero-carbon fuels.
Italy	No specific target on maritime sector; fragmented national regulations exist; largely guided by EU directives.	• Include shipping sector in NDC and establish clear targets in NAP. • Pursue MSR agreements with China to foster development of green hydrogen and ammonia. • Strengthen hydrogen energy initiatives and hydrogen ship fuel.
Greece	No specific target on maritime sector in NDP, but NECP (2019) includes section on shipping sector.	• Amend spatial planning laws for RES to attract investments in wind energy. • Create stable unified power system between mainland and the islands to stabilize energy for shipping.

5. Potential Measures to Decarbonize Maritime Transport

The possible measures to achieve decarbonization of international shipping can be categorized into three general categories including technological measures, operational measures, and alternative fuels and energy (Table 10). The respective emission-reduction potentials presented in each of the subsections are assessed individually.

Table 10 Overview of principal measures to reduce shipping's carbon emissions.

Type of Measures	Main Measures
Technological	Light materials, slender design, friction reduction, waste heat recovery
Operational	Lower speeds, ship size, ship–port interface
Alternative fuels/energy	Green hydrogen, green ammonia, fuel cells, electric ships, wind assistance, sustainable biofuels,[2] solar energy

5.1 Technological Measures

Improving energy efficiency through technological measures is the aim of the global regulation of the energy efficiency of ships. Regulation requires ships built after 1 January 2013 to comply with a minimum energy efficiency level, the EEDI included in the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI, which measures the CO_2 emitted (g/ton mile) based on ship design and engine performance data. The EEDI level is tightened incrementally every five years with an initial CO_2 reduction level of 10% for the first phase (2015–2020), 20% for the second phase (2020–2025), and a 30% reduction mandated from 2025 to 2030.

There are various concerns related to the effectiveness of the EEDI. Since the EEDI regulation affects only newbuild ships, it takes time for the regulation to cover the global fleet. The average age of the shipping fleet is approximately 25 years, which means that the large majority of ships will be covered by EEDI only by 2040. Insofar as the EEDI acts as a target, it cannot be considered to be a very challenging target: the attained EEDIs of newbuild ships largely exceed the currently-required EEDIs including Phase 3 requirements, even though they are not mandatory before 2025—in particular, those of containerships and general cargo ships (Transport & Environment, 2017; Hoen & Faber, 2017). The attained scores often do not reflect the use of innovative electrical or mechanical technology, but they can be simply achieved through optimization of conventional machinery or through a change the hull design (Hoen & Faber, 2017). The impact of EEDI on emission reductions in shipping are estimated to be small: only a marginal difference has been found in CO_2 emissions between EEDI and non-EEDI scenarios (Tristan Smith et al., 2016). For the EEDI regulation to have a larger impact, the mandated reductions or reference years would need to become more ambitious.

Technological measures include technologies that help ships increase their energy efficiency beyond EEDI. Covered by a large body of literature, measures listed in Table 11 are generally considered the major technological measures to increase the energy efficiency of ships. These technologies are available on the market, but not all options can be applied as a retrofit. It should be noted that the reduction potentials are variable throughout different ship types, weather or engine conditions, and operational profiles. Moreover, estimations from industry sources may be exceedingly optimistic and should be taken with caution.

Table 11 Main technological measures and associated fuel savings potential.

• Measures	• Potential Fuel Savings
• Lightweight materials	• 0–10%
• Slender hull design	• 10–15%
• Propulsion improvement devices	• 1–25%

Bulbous bow	2–7%
Air lubrication and hull surface	2–9%
Heat recovery	0–4%

Note: Emission reduction potentials are assessed individually. Ranges roughly indicate possible fuel savings depending on varying conditions such as vessel size, segment, operational profile, route, etc., hence limiting the possibilities for comparison. Numbers cannot be cumulated without considering potential interactions between the measures. Sources: (Bouman et al., 2017; Gilbert et al., 2015; IMarEST, 2011).

5.2 Operational Measures

We cover four different operational measures: speed, ship size, ship–port interface and onshore power (Table 12). Ship size developments refer to ship capacity utilization. The measure "ship–port interface" is related to a reduction in ship waiting time before entering a port. Shore power facilities are considered part of a larger set of port measures that could reduce emissions of ship operations. Both slower speed and increase in ship size (allowing for greater capacity utilization) have contributed to a decrease in shipping emissions over the last years.

Table 12 Main operational measures and whole-fleet CO2 reduction potential.

Measures	CO_2 Emissions Reduction Potential
Speed	0–60%
Ship size and capacity utilization	0–30%
Ship–port interface	0–1%
OPS	0–3%

Note: Emission reduction potentials concern the cumulative reduction potential for the entire ship fleet. Numbers cannot be cumulated without considering potential interactions between the measures. Sources: (Faber et al., 2017; Golias et al., 2009; Kiani et al., 2006).

A review of operational measures shows that slow steaming yields significant CO_2 emission reductions, e.g., a speed reduction of 10% translates into an engine power reduction of 27% (Faber et al., 2017). Lower speeds are more effective if design speeds of ships are brought down as well (Lindstad et al., 2011). Drawbacks of these measures include the potential need for additional vessels to maintain service frequency, longer lead times and the risk of modal shift of time-sensitive shipments to rail or road transport.

The largest vessels of all ship types emit less CO_2 per ton kilometer under conditions of full capacity utilization. CO_2 emissions could be reduced by as much as 30% at a negative emission reduction cost by replacing the existing fleet with larger vessels, according to Lindstad et al., 2012. The relationship between ship size and emissions is not linear but reflects a power-law relationship with diminishing marginal emission reductions as vessel size increases. However, as the newer (and more energy-efficient) ships are often larger ships, the effect of larger ships to aid in decarbonization could be overestimated (ITF/OECD, 2015).

Countries can achieve further reductions by smoother ship–port interfaces and on shore power supply. Ports currently generate approximately 5% of shipping's CO_2 emissions(Merk, 2014). If improved ship–port interfaces reduced ship waiting times—and the use of auxiliary engines in ports—to zero, the carbon emission reductions would amount to approximately 1% of total shipping emissions (ITF/OECD, 2018). Optimized voyage planning, collaboration and real-time data exchange can further contribute to improved berth planning. OPS facilities in ports allow ships to turn off their engines and connect to the electricity grid to serve auxiliary power demand. The use of OPS requires retrofits on the ship.

5.3 Alternative Fuels and Energy

Although a range of alternative fuels and energy have lower or zero ship emissions when used for ship propulsion, upstream emissions may arise in the production process. In Table 13, we cover a range of alternative fuels and energy sources. Not all of these options have reached market maturity yet.

Table 13 Main alternative fuels and energy, and associated fuel savings potential.

Measures	Potential Fuel Savings
Electricity and hybrid propulsion	10–100%
Synthetic fuels (hydrogen and ammonia)	0–100%
Fuel cells	2–20%
Advanced biofuels	25-100%
Wind assistance	1–32%

Note: Emission-reduction potentials are assessed individually. Ranges roughly indicate possible fuel savings depending on varying conditions such as vessel size, segment, operational profile, route, weather conditions, etc., hence limiting the possibilities for comparison. Numbers cannot be cumulated without considering potential interactions between the measures. Considering upstream emissions of synthetic fuels and electricity, an almost 100% emission reduction can be reached only if generated from renewable energy sources. Sources: (Anderson et al., 2015; Bicer & Dincer, 2018; Bouman et al., 2017).

The emission-reduction potential of biofuels and synthetic fuels depends to a great extent on their production methods. Advanced biofuels from both the second and third generations could, in theory, reduce potential adverse social and environmental effects by using degraded land or residual biomass. Yet more knowledge on their performance and physical properties, as well as more testing and standardization, would be required for broader use by the shipping industry (Hsieh & Felby, 2017). Synthetic fuels can be produced via electrolysis powered by wind, hydro or solar energy to avoid lifecycle emissions arising from production (Bicer & Dincer, 2018). Production of synthetic fuels could easily develop where renewable energy sources are abundant or where they can produce a large excess output (IEA, 2017). Although LNG has been shown to reduce CO_2 emissions to some extent, it is unlikely to reduce overall climate impact because of its methane content (a short-lived potent climate forcer) vis-à-vis heavy fuel oil (HFO) (T Smith, 2018).

Further emission reductions could be reaped by using hybrid systems involving fuel cells and batteries. The efficiency of fuel cells greatly depends on the fuel cell type and the fuel used (GL, 2017). All-electric propulsion is currently used in short-range passenger shipping (e.g., in Norway) or short-range river transport (e.g., in China or Netherlands). Hybrid electric systems may provide an interesting option for longer distances, yielding potential fuel savings of 10–40% and payback times as low as one (GL, 2016).

In addition, wind power applications further decrease a ship's fuel demand. Especially if wind is combined either with other technologies, slow steaming and other incremental efficiency improvements, or with photovoltaic technology emissions can be dramatically reduced. (Teeter & Cleary, 2014; Traut et al., 2014). Drawbacks include their potential interference with cargo handling. An extensive review of these measures and their potentials and disadvantages is included in a recent ITF and OECD report (ITF/OECD, 2018).

Box 3: The limited role for LNG in greening the shipping sector

LNG as an alternative fuel has many drawbacks in terms of GHG emission reduction potential.

In comparison to traditional oil-derived bunker fuels, LNG has a lower CO_2 content and emits lower quantities of sulfur oxides (SOx), nitrogen oxides (NOx) and particulate matter (Baresic et al., 2018). As a result, LNG has become a preferred strategy by port authorities, policy makers and ship owners for the greening of the shipping sector.

However, LNG is not an advisable investment for decarbonizing the shipping industry. Methane (CH_4) gas – which could be emitted due to methane slippage – could bring about a warming effect up to 28 times higher compared to that of CO_2 (Englert et al., 2018). Another concern is that LNG boils off when ships anchor at ports for an extended period of time (Moirangthem, 2016), meaning it has to be de-bunkered to avoid a dangerous increase in tank pressure (McGill et al., 2013).

Type	Size (tons)	Engines	Engine Cost	Fuel System Cost	TOTAL CONVERSION COST
Tug	150	2 × 1,500 HP	$1.2 million	$6.0 million	$7.2 million
Ferry	1,000	2 × 3,000 HP	$1.8 million	$9.0 million	$10.8 million
Great Lakes Bulk Carrier	19,000	2 × 5,000 HP	$4.0 million	$20 million	$24 million

Table 14 Costs Associated with Converting Marine Vessels to LNG Operation

A recent World Bank report strongly contests the notion of using LNG as a transitional or alternative fuel for the shipping sector, based on LNG's insufficient GHG emission-reduction abilities and unclear cost-benefit outcomes (Englert et al., 2021). The report estimates that using LNG as transitional fuel requires an additional $186 billion of investment for the decarbonization of maritime transport by 2050, as compared to a transition straight to zero-carbon fuels (Englert et al., 2021). This cost includes investment in pipelines, LNG storage, feeder and bunker vessels, trucks and berth and administration services. Retrofitting is expensive, and the payback period is often longer than shipowners plan to control a given ship (Stulgis et al., 2014). Depending on the type of vessel, retrofitting is estimated to cost up to $24 million dollars, which includes engine costs and fuel system costs (McGill et al., 2013). Furthermore, infrastructure for the LNG supply chain and bunkering system could become stranded assets when future fuel will need to rely on zero-carbon fuels to achieve climate goals.

A promising alternative to LNG is green hydrogen and ammonia. The key advantage of transitioning directly to hydrogen over LNG and other fuel alternatives is the relative ease of retrofitting existing ships, some of which could operate on hydrogen without any change (Reinsch, 2021). Retrofitting ships for hydrogen requires installing fuel cell technology, a relatively inexpensive and uncomplicated process. The existing global hydrogen market could already provide clean fuels to the shipping industry and, unlike LNG, hydrogen can be stored in large quantities and over long periods of time (Englert et al., 2021). Although hydrogen is not yet a popular shipping fuel, public policy and investment in the technology and bunkering system can make it more cost-effective than LNG. More research is needed around the potential and impacts of hydrogen fuel use, especially around air quality implications.

6. International and Chinese Practices on Green Shipping Development

6.1 International Practices

International green shipping practices are mainly concentrated in developed economies and maritime powerhouses such as the EU, USA, UK, Japan, Korea, and Singapore.. They are leading in clean energy, especially decarbonization and zero-carbon energy application and development, green shipping policy research and maritime governance, low-carbon and emission reduction technology innovation and application, funding and concept leadership, policy incentive and market guidance, and rich technology reserve, leading global shipping industry to green development.

6.1.1 Application of Intelligent and Green Low-Carbon Technologies on Ships

Swedish ferry company Stena Line has reduced its total CO2 emissions by 1.7 percent, equivalent to a total of 24,000 tons of CO2 said in its 2019 sustainability report (Stena Line, 2019). The latest reduction data means the company is 10 years ahead of the industry's emissions reduction target and has already met the International Maritime Organization (IMO) 2030 target of reducing CO2 emissions by 40 percent between 2008 and 2030. Over the past 10 years, Stena Line has taken more than 320 energy-saving actions on board and onshore, including technology applications and operational improvements that have resulted in increased energy efficiency.

Intelligent auxiliary and green technologies are widely used on Stena Line's recently built vessels, and artificial intelligence technology calculates the highest operating efficiency of fuel and main engines, reducing fuel consumption by 2-3% of the voyage. Route design and ensuring the safety of a ship is a demanding task. With the help of artificial intelligence, ships can learn how to optimize routes more efficiently, match main engine power and improve energy efficiency.

Stena Line plans to be a zero-emissions company by 2050 in line with international community goals, has almost completely eliminated the use of single-use plastics on its ships, and is working to improve the use of recyclable materials in offices, ports and terminals, reducing emissions to the ocean and air, while exploring and evaluating future fuels. It is currently involved in the development of the world's first fossil fuel-free, fully battery-powered passenger ro-ro vessel. The lightweight Stena Elektra is 200 meters long, can accommodate 1,000 passengers and 3,000 meters of lane length cargo, and is capable of sailing 50 nautical miles on a single charge on the Gothenburg-Friedrichshafen route. Stena Line is working with Volvo Group, Scania and the Port of Gothenburg to look at options to expand the current power of only 60-70 megawatt hours by adding fuel cells, hydrogen and biofuels. The ship is not expected to be put into service until 2030.

6.1.2 Japan's Electric Boat and Carbon Capture Technology

NYK Japan will build two electric tankers, scheduled to be completed in March 2022. When completed, the vessels will achieve zero greenhouse gas emissions, while the burden of voyage management will be reduced compared to existing tankers. The planned electric tanker will use an electric engine developed by large Japanese machinery manufacturer Kawasaki Heavy Industries. The vessel is designed to be 60 meters in length and 499 tons in tonnage, and will be equipped with lithium batteries equivalent to the power of approximately 100 electric cars, achieving zero greenhouse gas emissions. The completed electric tanker is planned to serve as an oil transportation task in the waters of Tokyo Bay, in addition, in the event of a disaster can also deliver electricity to coastal facilities. Although the cost of this electric tanker is higher than the existing fuel-powered tankers, the burden of navigation management will be reduced, which is expected to alleviate the current shortage of crew and will promote the spread of electrification in the maritime industry.

Japanese shipping giant Kawasaki K Line will trial the world's first carbon capture device on one of its ships. Kawasaki K Line is partnering with Mitsubishi Shipbuilding to install a small-scale carbon dioxide capture demonstration unit on board and to conduct design research and development of a compact device. The project involves converting an existing CO2 capture system for use in a land-based power plant to an offshore device for use on board a ship. Not only the effectiveness of capturing and storing CO2 from ship emissions will be verified, but the operability and safety of the offshore CO2 capture facility can also be demonstrated. These demonstration tests are designed to facilitate the development of compact equipment required by the marine environment while meeting the system requirements for continuous and stable operation at sea. The two-year project begins with the initiation of risk identification evaluation of the demonstration unit, which will be verified by the Japan Classification Society. Mitsubishi Shipbuilding will then begin the development and construction of a small-scale CO2 capture demonstration unit and evaluation of system safety. The captured CO2 is expected to be recovered as a new source of CO2 for optimizing the oil recovery process or as a feedstock for fuel synthesis through methanation.

6.1.3 Norway Research on Ammonia Fuels

Norway's maritime transport industry is making a world-leading attempt to eliminate greenhouse gas emissions by introducing innovative marine fuels. Statoil Equinor and offshore support vessel operator Eidesvik Offshore will collaborate to develop and test the use of ammonia as a marine fuel, and test ammonia fuel cells on Eidesvik's platform supply vessel Viking Energy. “The Viking Energy, an LNG-powered vessel, will meet 60 to 70 percent of its energy consumption and 90 percent of its total power requirements using ammonia fuel during the trials, demonstrating the viability of ammonia fuel for long-range, zero-emissions navigation and offshore operations. Fuel cell modules with a total power of 2 MW will be installed on the Viking Energy, sustaining the vessel for up to 3,000 hours per year. The vessel will use ammonia power for a year-long transport between ports and offshore facilities, with the ammonia fuel powering the vessel while berthed at the dock. Wärtsilä will provide the power technology and systems for ammonia storage and distribution for the Viking Energy, Prototech is providing the fuel cell system and Yara is providing the ammonia fuel.

6.1.4 Shipping giants' choice of decarbonized energy

To accelerate the decarbonization process, the shipping giants are exploring the application of alternative fuels including methanol, hydrogen, ammonia, biomethane and other biofuels. For example:

Table 15 Shipping giants' choice of decarbonized energy

Shipping giants	The choice of decarbonized energy
Maersk	Participating in several green ammonia projects, and studying the feasibility and economics of methanol for ship power at the same time. Maersk has announced that it will commission methanol-powered feeder container vessels in 2023 and that all its own new vessels will be able to use carbon-neutral fuels in the future. Maersk expects multiple fuel solutions to co-exist in the future, with methanol (e-methanol and bio-methanol) and ammonia remaining the future fuel of choice.
MSC	has expressed its interest in hydrogen by joining the Hydrogen Council, a global industrial hydrogen fuel advocacy body, as a steering member

CMA-CGM	Announced support for a project to produce 12,000 tons of biomethane, which could meet the annual fuel consumption of two 1,400 TEU container ships.
COSCO Shipping Container Lines	Actively promotes the application of clean energy in the field of ship fuel and also hopes to join hands with more and more peers, petroleum corporation and technology companies to jointly promote cleaner, lower carbon and zero emission ship fuel.
Hapag-Lloyd	Believes that there is no realistic alternative to LNG for the global merchant fleet. The only alternative fuel currently available is LNG, and while it is an interim solution, it is the only one that is realistic and feasible in terms of practical solutions to address climate change.
Ocean Netlink Japan	Has verified the feasibility of biofuels that could help liner companies meet their carbon reduction targets for 2030 and 2050. Ocean Netlink Shipping has also made several attempts at other clean energy applications
Hyundai Merchant Marine	Has formed an R&D team to accelerate research that includes exploring the commercial viability of hydrogen power systems

6.2 Chinese application of green technologies on ships

China's shipping industry has paid high attention to green and low-carbon development in recent years, and under the incentive of government's supporting policies, the research and application of green technologies have made rapid progress, and green, low-carbon and intelligent have been taken as important grasp to achieve high-quality development. Both ocean-going, coastal and inland waterways shipping have taken green, low-carbon and sustainable as the future development direction. Several representative cases of green shipping development were selected, including hydrodynamic energy-saving device application, sail aids navigation, solar energy application, gas film drag reduction, intelligent ships, shore power promotion and carbon neutral voyage for introduction.

6.2.1 Hydrodynamic Energy Saving Devices

6.2.1.1 Application of Hydrodynamic Energy-Saving Devices for 57,000-ton Bulk Carriers

The 57,000-ton bulk carrier is one of the most owned vessel types in the dry bulk market. China Ship Scientific Research Center has carried out the design and development of hydrodynamic energy-saving devices for this vessel type, and finally adopted the combined hydrodynamic energy-saving solution of forward pre-rotating guide wheel and propeller hub vortex fin. Initial tests demonstrated significant energy savings from forward pre-rotating guide wheel and propeller hub vortex fin - 5.4% and 3.0% respectively. The application and test results showed that the energy-saving effect has the potential to reach 9.0%, and the average daily fuel saving can be more than 2 tons. It is estimated that companies can recover the investment costs within one year, a huge economic benefit.

Due to its excellent performance, shipowners now widely use this energy-saving device. In 2018, the national energy-saving center also ranked the project number one.

6.2.1.2 Application of Hydrodynamic Energy-Saving Device for 400,000-ton Ultra-Large Ore Carrier

In March 2016, China COSCO Shipping, China Merchants Group and ICBC Financial Leasing Co., Ltd. signed an agreement with Vale of Brazil to order thirty 400,000-ton ultra-large ore carriers (Valemax-II). These carriers have green, environmental protection, energy-saving and safety features, including a standout water-powered energy-saving device.

The China Ship Scientific Research Center combined the front pre-rotating guide wheel, the high-efficiency propeller and the propeller hub vortex eliminating fin to achieve the best overall energy-saving effect based on an integrated design concept. It was verified by a foreign third-party pool test and won the bid with the best overall performance due to its high propulsion efficiency, the best energy-saving effect and no risk of cavitation and spalling. The water-powered energy-saving device won the supply order for all 30 vessels. According to the evaluation, after the device's installation, each ship can save about 5 tons of fuel per day, save about 450,000 US dollars in fuel costs and reduce more than 3,000 tons of CO_2 emissions per year – outstanding economic and emissions-reduction benefits.

6.2.2 Sail-Powered Technology

The world's first sail-powered Very Large Crude Carrier (VLCC) became a reality in November 2018. The 308,000 ton VLCC, "Kaili", was financed and built by China Merchants Ship.

The sail is one of the most critical pieces of equipment on the vessel, integrating machining, hydraulic, electrical, structural welding and other specialties. The sail is composed of a slewing mechanism, a mast and a sail wing.

Wing-type sail boosting results in significant energy savings. With the sail assistance, the load power of the ship's engine can be reduced, saving an average of 3% of fuel consumption per day.

Figure 7 Very Large Crude Carrier "Kaili"

6.2.3 Solar Energy Technology Application

The large-scale application of photovoltaic panels on ships to produce solar energy is constrained by bulk carrier hatch opening and closing, pipe systems and container ship deck loading. COSCO Shipping Group carried out research on the application of solar energy on Roll-on/roll-off (ro-ro) vessels. Since the top deck of ro-ro ships is not loaded with cargo, compared with other types of ships, there is more space for the application of photovoltaic panels.

COSCO Tengfei, which is part of the COSCO Shipping Special Transport Company, completed the installation of China's first and the world's largest ship solar off-grid hybrid photovoltaic power generation system in March 2014, and the application of solar energy on large ro-ro ships became a reality. COSCO Tengfei is carrying the world's largest 143KW off-grid solar photovoltaic system to sail to the oceans.

Figure 8 Solar energy technology application in COSCO Tengfei

According to the test results, it can provide 16 hours of power supply per day under sufficient sunlight, which is equivalent to saving 0.46 tons of fuel per day, with significant economic and environmental benefits. This project has put COSCO Shipping at the world’s forefront in promoting energy-saving and emission-reducing green ships.

Chapter IV "The Belt and Road Initiative" Marine Biodiversity Conservation Research

1. Status Quo of the BRI Marine Biodiversity Protection

Marine biodiversity is an important part of global biodiversity. Among the 34 phyla found at present, 33 are marine phyla, and organisms of 15 phyla only live in the marine environment. The extensive influence of human activities on the ocean has led to the decline of species diversity and abundance. The socio-economy of coastal countries is closely related to the development and utilization of marine resources. How to promote the sustainable development and high-level protection of marine biodiversity in countries along the BRI has become the focus of the construction of the BRI.

1.1 Status Quo of Marine Biodiversity in Countries Along the BRI

Southeast Asia, Central Africa and South America are considered as global biodiversity hotspots and priority areas for biodiversity conservation. The BRI passes through Southeast Asia and Central Africa, countries along which cover most of the global biodiversity hotspots (Meng et al., 2019), 27 of 35 globally recognized biodiversity hotspots. Most coastal countries are located in tropical and subtropical regions, with abundant marine biodiversity.

For example, ASEAN is the global tropical marine biodiversity center, with the most diversified coral reef, mangrove and seagrass bed ecosystems in the world. Especially the Coral Triangle, a triangular sea area consisting of the Philippines, Malaysia, Indonesia, Papua New Guinea and Solomon Islands, is the region with the highest marine biodiversity in the world, with 75% of coral species and 51 of 70 mangrove species in the world (Xu, 2021). At present, ASEAN has established a number of national natural conservation zones, national parks and genetic species reserves, such as Tubbataha Reefs Natural Park in the Philippines and Tarutao Marine Park in Thailand.

India has a coastline of 7,517 kilometers, including 5,423 kilometers along the Indian Peninsula and 2,094 kilometers along the Andaman, Nicobar and Lakshadevi Islands, with the exclusive economic zone covering an area of 2.02 million square kilometers. There are many ecosystems in the coastal areas of India, such as mangroves, estuaries, coral reefs, seagrass beds, lagoons, sand dunes, rocky shores, cliffs, intertidal mudflats, etc. They are home to about 20,000 animal species communities, of which 1,180 species are threatened by different categories of dangers and need to be protected immediately (Sahib， 2021). At present, 25 marine protected areas and 106 important coastal and marine areas (ICMBAs) have been established.

Kenya in Africa lies across the equator, between 4.5 degrees south latitude and 4.5 degrees north latitude, with a coastline of about 640 kilometers and a total sea area of about 230,000 square kilometers. Marine biodiversity area is distributed in coastal communities in East Africa, including Ram Island and kister Island in the Indian Ocean. Coral reefs are the dominant coastal marine ecosystem in Kenya, and lagoons and streams protected by reef ridges create habitats for seaweed and mangroves.

With the continuous deepening of global marine environmental governance, countries along the BRI have improved their marine biodiversity conservation capacity and level through international compliance, domestic legislation, regional cooperation and the establishment of marine protected areas. Most countries have joined the Convention on Biological Diversity, and have continuously improved their ability to implement the Convention. The number and area of marine protected areas are increasing year by year, and the areas and types covered are also increasing.

Table 16 Area and Coverage of Marine Protected Areas in Major Coastal Countries along the BRI

Country	Area of protected area (square kilometers)	Coverage area （%）	Country	Area of protected area (square kilometers)	Coverage area （%）
China	48126	5.48	Pakistan	1707	0.77
South Korea	7979	2.46	Bangladesh	4530	5.36
Japan	332691	8.23	Maldives	623	0.07
Indonesia	181865	3.06	Jordan	1	0.98
Thailand	13412	4.37	Kuwait	162	1.36
Malaysia	14930	3.31	Saudi Arabia	5495	2.49
Vietnam	3630	0.56	Turkey	270	0.11
Combodia	691	1.44	Egypt	11716	4.95
Philippines	32010	1.74	United Arab Emirates	6281	11.48
Myanmar	2457	0.48	Kenya	857	0.76
Brunei	52	0.2	Tanzania	7330	3.02
India	5543	0.24	Greece	22326	4.52
Sri Lanka	399	0.07	Italy	52465	9.74

Note: The data comes from World Protected Area Database (WDPA).

1.2 Status Quo of Marine Biodiversity Protection in China

1.2.1 China's Marine Biodiversity Conservation Policies

China attaches great importance to biodiversity conservation, and has set up a National Committee for Biodiversity Conservation under the State Council, which is led by the Deputy Prime Minister. Since the 18th National Congress of the Communist Party of China, guided by Xi Jinping's ecological civilization thought and coordinated by China National Committee for Biodiversity Conservation, China has deepened the implementation of *China Biodiversity Conservation Strategy and Action Plan (2011-2030)*, carried out a series of activities of "10-year China Action for the United Nations Biodiversity", implemented major biodiversity conservation projects, and actively promoted the Aichi target (2020 global biodiversity target) in China, which has delivered remarkable achievements in biodiversity conservation. "Implementing major ecological system protection and restoration projects, optimizing the ecological security barrier system, building ecological corridors and biodiversity protection networks, and improving the quality and stability of ecosystems" was included in the important reform measures of the 19th National Congress report of the CPC and 2019 key work points of the central government's comprehensive deepening reform. At the 2020 United Nations Biodiversity Summit, Chinese President Xi Jinping emphasized that "biodiversity is not only the foundation of sustainable development, but also the goal and means" "We must earnestly fulfill our commitments, do a good job in implementing the goals, effectively reverse the loss of biodiversity, and jointly protect the earth's homeland".

The existing national top-level design puts forward specific requirements for marine biodiversity protection. The *China Biodiversity Conservation Strategy and Action Plan (2011-2030)* issued by the Ministry of Ecological Environment (the former Ministry of Environmental Protection) proposed to improve relevant policies, regulations and systems of biodiversity conservation, strengthen the in-situ conservation of biodiversity, rationally carry out ex-situ conservation, further strengthen the capacity building of biodiversity monitoring, and improve the level of early warning and management of biodiversity.

In 2020, the National Development and Reform Commission and the Ministry of Natural Resources jointly issued the *National Master Plan for Major Projects for Protection and Restoration of Important Ecosystems (2021-2035)*, which laid out seven major regional ecological restoration projects, including major projects for coastal zone protection and restoration, and proposed to comprehensively carry out shoreline beach restoration, habitat protection and restoration, prevention and control of alien invasive species, and construction of marine protected areas, so as to promote the protection of marine biodiversity.

1.2.2 Construction and Management of Marine Nature Reserves

Since the establishment of the first marine reserve-Shedao Laotieshan Nature Reserve in 1963 (Wu, 2015), China has kicked off the construction of marine reserve. After the promulgation of *Marine Environmental Protection Law* and *Wildlife Protection Law*, the number and area of China's marine nature reserves have increased significantly, and the construction of the reserves has been further accelerated. In 1990, the State Council approved the establishment of the first batch of five national marine nature reserves, including Changli Gold Coast in Hebei, Nanji Islands in Zhejiang, Shankou Mangrove in Guangxi, Dazhou Island and Sanya Coral Reef in Hainan. In 2005, according to the *Marine Environmental Protection Law*, the State Oceanic Administration approved the establishment of the first special marine reserve, Ximen Island National Marine Special Reserve in Yueqing, Zhejiang Province. In 2011, according to the *Interim Measures for the Administration of Aquatic Germplasm Conservation Zone*, the agricultural department set up aquatic germplasm conservation zones, which further enriched and improved the types of marine protected areas. Up to now, China has established 271 marine nature reserves and special marine reserves (including marine parks) at all levels, with a total area of more than 120,000 square kilometers, and 51 national aquatic germplasm conservation zones with an area of about 74,000 square kilometers.

With the joint efforts of the state and local governments, the number and area of marine nature and special protection areas are increasing rapidly, and the types of protected species are becoming more and more abundant. For instance, rare and endangered marine species such as spotted seals, Chinese white dolphins, dugongs, amphioxus, horseshoe crabs, seabirds and corals, marine natural relics and landscapes such as shell dikes, Lulian sand dikes, oyster reefs, marine erosion landforms and sandy coasts, and typical marine ecosystems such as mangrove, coral reef, estuary wetland, islands are effectively protected, and the network of marine protected areas in China's coastal waters has been continously improved.

Marine biological species are rich in diversity. Up to now, more than 28,000 species of marine life have been recorded in China, accounting for about 11% of the total known marine life species in the world, ranking third in the world after Australia and Japan. China's marine biodiversity occupies an important position in the world. There is a great difference in water temperature between the south and the north of China's sea area, and there are various temperature species and flora such as cold temperature species, warm temperature species, subtropical species and tropical species. Among them, the species in China's sea area are mostly warm water species (tropical species and subtropical species), but few widespread species and warm temperature species. In spatial distribution, the species number of each biological community generally shows a decreasing trend from south to north.

Marine ecosystems are various in type. China's sea areas include Bohai Sea, Yellow Sea, East China Sea, South China Sea and some sea areas east of Taiwan Province, which are in the shape of a NE-SW arc surrounding the mainland, with rich marine and coastal ecosystems. According to the types of ecosystems, China's marine ecosystems mainly include coastal wetland ecosystems, coral reef ecosystems, upwelling ecosystems and deep-sea ecosystems. According to habitat types, there are many marine habitats in China, such as estuaries, bays, coastal wetlands, mangroves, coral reefs, lagoons, island reefs, upwelling, seagrass beds and so on.

Marine biological genetics is complex in diversity. Artificial cultivation was carried out relatively early in China for kelp, laver and Undaria pinnatifida, and has now been extended to fish, shrimps and crabs, shellfish and other populations. Besides, China has made progress in germplasm identification, phylogeny, population genetic structure analysis and improved seed cultivation. Generally speaking, the genetic diversity of most marine biological populations in China is relatively high, but the genetic diversity of different marine biological populations is quite different. The extensive aquaculture activities in China, due to the lack of effective genetic resources management, have caused the bottleneck effect of population genetic diversity, genetic drift, inbreeding decline and other problems, resulting in the level of genetic diversity of aquaculture population being lower than that of wild natural population (Li, 2019).

2. Cooperation on the BRI Marine Biodiversity Conservation

2.1 Global Cooperation on Marine Biodiversity Conservation

2.1.1 *United Nations Convention on the Law of the Sea* and Related Treaties

At present, the international community has initially established a marine environmental governance system based on two types of treaties: marine environmental pollution control and marine living resources protection. The United Nations Convention on the Law of the Sea adopted in 1982 provides an international framework for better management of marine resources. In 1995, FAO of the United Nations adopted the Code of Conduct for Responsible Fisheries, which formulated detailed guidelines on fishing to protect the marine ecosystem and biodiversity. With the increasing recognition of the benefits provided by healthy marine ecosystems to human beings, the protection of marine biodiversity has become the priority of the scientific community, resource managers and national and international policy agreements including the parties to the Convention on Biological Diversity. At present, the protection and sustainable utilization of marine and coastal biodiversity has become an important topic in the negotiation of international multilateral treaties such as the Convention on Biological Diversity and the United Nations Convention on the Law of the Sea.

At the same time, countries pay more and more attention to the construction of marine protected areas, and take measures such as prohibiting fishing, mining or restricting the navigation of commercial vessels in the protected areas to prevent over-exploitation of marine resources and protect marine biodiversity (Liu, 2021). The World Database of Protected Areas (WDPA) shows that the number and spatial scope of marine protected areas have increased rapidly. Since 2000, the area of marine protected areas has increased by more than 10 times from 2 million square kilometers, and the global coverage rate of marine protected areas will be 7.68% in 2021. The whole world can be divided into areas within national jurisdiction (national waters) and areas in international waters (areas beyond national jurisdiction, namely ABNJ). The proportion of marine protected areas created in national waters is about 17.86%, which is much higher than 1.18% of ABNJ. At present, 66.1% of marine and coastal key biodiversity areas (KBA) are partially or completely covered by marine protected areas.

2.1.2 *the Convention on Biological Diversity on the protection of marine biodiversity*

The *Convention on Biological Diversity* is an important convention in the field of biodiversity conservation in the international community. It came into effect on December 29th, 1993. At present, there are 196 parties in the world. The marine biodiversity under the convention mainly focuses on the following topics: coping with the impacts of human activities and climate change on marine and coastal biodiversity, tools for the protection and sustainable utilization of marine and coastal biodiversity, marine protected areas and EBSAs.

Table 17 Ocean-Related Contents in Successive Conferences of the Parties to the *Convention on Biological Diversity*

Time	Meeting	Ocean part
1995	COP2	Make marine and coastal biodiversity a formal topic for the first time.
1998	COP4	Adopted the Work Programme on Marine and Coastal Biodiversity.
2002	COP6	Put forward the goal of "establishing a representative network of marine protected areas by 2012".
2004	COP7	Decided to include marine biodiversity beyond areas of national jurisdiction (BBNJ) in the work plan on marine and coastal biodiversity.
2006	COP8	Improve and develop a set of comprehensive scientific standards for marine areas that confirm that open marine waters and deep-sea habitats need protection and have ecological or biological significance before COP9.
2008	COP9	Adopt the scientific guidelines for determining ecologically or biologically significant sea areas to be protected in high seas and deep-sea habitats and the scientific guidance for establishing the site selection of representative marine protected areas including high seas and deep-sea habitats.
2010	COP10	The implementation of the Work Programme on Marine and Coastal Biodiversity was evaluated, and the Biodiversity Strategic Plan for 2011-2020 and the corresponding biodiversity targets (Aichi targets) were released.
2012	COP11	Adopt the Draft Summary Report on Describing Areas Meeting Scientific Standards of Marine Areas of Important Ecological or Biological Significance.
2014	COP12	207 sea areas in seven regions, including the South Indian Ocean, the tropical and temperate zone of the eastern Pacific Ocean, the North Pacific

		Ocean, the Southeast Atlantic Ocean, the Arctic Ocean, the Northwest Atlantic Ocean and the Mediterranean Sea, were included in the global EBSAs list.
2016	COP13	Through "Specific Work Program on Biodiversity and Acidification in Cold Water Area", "Marine Spatial Planning and Training Initiative", etc.
2018	COP14	Concerned about the impacts of marine debris and microplastics pollution on marine and coastal biodiversity and habitats.

2.2 Cooperation on the BRI Marine Biodiversity Conservation: A Case Study of ASEAN

The natural distribution of marine biodiversity always crosses national boundaries, and the understanding and protection of global biodiversity cannot be separated from the close cooperation of various countries. Countries along the BRI have carried out extensive and in-depth international cooperation in biodiversity.

2.2.1 China-ASEAN environmental cooperation mechanism

In 2003, China and ASEAN signed the *Joint Declaration on China-ASEAN Strategic Partnership Towards Peace and Prosperity*, emphasizing strengthening cooperation and strengthening "mutual cooperation mechanism in these fields" through "more exchanges in science and technology, environment, education, culture and personnel". *China-ASEAN Environmental Protection Cooperation Strategy 2009-2015* and *China-ASEAN Environmental Protection Cooperation Strategy (2016-2020)* all regard biodiversity and ecological protection as one of the priority cooperation areas. Under the framework of the cooperation strategy and its action plan, the exchange and cooperation between China and ASEAN countries in the field of marine ecosystem and biodiversity protection will be promoted by holding the China-ASEAN Coastal Wetland Ecological Protection and Restoration Technical Cooperation Forum, signing the Mangrove Protection Cooperation Memorandum, and holding the China-Cambodia Ecosystem and Biodiversity Protection Exchange Seminar.

2.2.2 COBSEA

COBSEA is one of the 18 regional sea action plans organized and implemented by the United Nations Environment Programme. It was established in 1981, and its member countries include Cambodia, China, Indonesia, south Korea, Malaysia, Philippines, Singapore, Thailand and Vietnam. Its purpose is to sustainably manage the east Asian sea and its coastal environment through dialogue and cooperation. As the United Nations starts negotiations on biodiversity outside the sea areas under national jurisdiction in 2017, the Coordinating Body of the East Asia Sea will include marine biodiversity protection and network construction of marine protected areas in its governance scope.

2.2.3 ASEAN biodiversity conservation cooperation

ASEAN attaches great importance to biodiversity conservation and has a relatively complete governance system in biodiversity conservation. In 1998, the ASEAN Regional Center for Biodiversity Conservation (ARCBC) was established, which laid an important foundation for intergovernmental cooperation in the field of biodiversity conservation. In 2005, the ASEAN Biodiversity Center (ACB) was established, which comprehensively strengthened biodiversity conservation in ASEAN, published the ASEAN Biodiversity Outlook, etc., promoted cooperation among governments, international organizations and other stakeholders, supported ASEAN countries to ratify and implement the Nagoya Protocol, and cooperated with three non-ASEAN partner countries (Japan-ASEAN Integration Fund Project, ASEAN-China Environmental Cooperation Action Plan, and ASEAN-Korea Environmental Cooperation Project).

2.3 Problems in the Cooperation of the BRI Marine Biodiversity Conservation

Although countries along the BRI are rich in marine biodiversity, the protection of marine biodiversity is very fragile compared with economic development. In particular, while developing economy and improving people's livelihood, some economically underdeveloped countries excessively ask for and exploit marine living resources, thus damaging the marine ecological environment. The dense population and rapid economic development have increased the demand for marine resources, and the pollution caused by backward production methods has destroyed the biodiversity and marine ecological environment in this region.

2.3.1 The Bilateral and Multilateral Cooperation Mechanism for Marine Biodiversity Conservation is Imperfect

Countries along the BRI have carried out various forms of international cooperation in marine ecological environment protection. These bilateral and multilateral cooperation have played an important role in marine biodiversity protection and achieved certain results. However, most of the bilateral and multilateral cooperation on marine biodiversity protection is mainly in the aspects of conference exchange, experience sharing and personnel exchange visits, and no normalized and stable mechanism has been established. In particular, there are relatively few specific action plans and substantive cooperation projects, and there is a lack of demonstration projects that have good results and can be replicated and promoted, and it is impossible to form a regional general cooperation mechanism and plan.

2.3.2 Regional cooperation in marine biodiversity research needs to be strengthened

Countries along the BRI have different levels of scientific research on marine biodiversity protection. Inter-regional scientific research cooperation will help countries exchange their needs and improve their scientific research ability and protection level in marine biodiversity. At present, from a regional perspective, the scientific research cooperation between China and ASEAN is relatively close, and the cooperation between other countries along the BRI needs to be strengthened. In terms of the cooperation content, there is more cooperation in technical aspects such as typical marine ecosystem and protection area survey, and less communication in policy aspects such as biodiversity compliance and environmental laws and regulations. In the next step, it is urgent to expand the breadth and depth of regional cooperation, bring more countries into the system of marine biodiversity conservation in the BRI, deepen scientific research cooperation at the technical level, and gradually carry out exchanges at the policy and strategic level.

2.3.3 The Protection of Marine Biodiversity Lacks Financial Guarantee

Capital is an important foundation and guarantee for regional cooperation in ecological environment (Qu et al., 2018). Countries along the BRI, starting from their own national interests and ecological environment protection strategy, will inevitably focus on and tilt in the specific ecological environment protection field, which is directly related to the priority and financial support of countries in ecological environment protection cooperation projects. Although marine biodiversity is an important part of cooperation in marine ecological environment protection, compared with onshore biodiversity protection, the cooperation projects and financial guarantee are not stable and sufficient. At present, it is urgent for governments of all countries to increase financial support for marine biodiversity conservation, strengthen research topics and projects at the level of dual multilateral mechanisms and platforms, and expand investment and financing channels to attract more green finance to marine biodiversity conservation projects, so as to enhance the ability of financial support.

Chapter V Policy Recommendations for the BRI Marine Interconnection Green Development

1. Status Quo and Trends of BRI Marine Interconnection Green Development

As the hub of transportation and the window of external communication, the port plays an important role in promoting international and domestic trade and regional development, and is the key node of the BRI maritime interconnection. The port carries the strategic mission of the Maritime Silk Road, and the green port is the inevitable requirement of the BRI green development.

In recent years, the world shipping industry has paid great attention to the green and low carbon development. Under the encouragement of the government's relevant supporting policies, the research and development and application of green technologies have made positive progress. With the improvement of environmental protection requirements of the shipping industry, the continuous maturity of energy-saving and emission-reduction technologies of ships, the cooperation of government and industry policies and incentive mechanisms, and the use of technologies such as hydrodynamic energy-saving technologies, solar energy and wind energy, mature green and low-carbon technologies have been widely used through ship renovation and new shipbuilding projects.

With the continuous deepening of the construction of the BRI, biodiversity and ecological protection in the BRI participating countries have gradually become hot issues. Especially, the socio-economic development of coastal countries is closely related to the development and utilization of marine resources. How to promote the sustainable development and high-level protection of marine biodiversity in countries along the BRI has become a key issue during its construction.

Guided by the "Silk Road Spirit" and the "Community of Marine Destiny" concept of peaceful cooperation, openness and tolerance, mutual learning and mutual benefit, and relying on the BRI diversified cooperation platforms such as the BRI International Alliance for Green Development, the China-ASEAN Environmental Cooperation Mechanism and the East Asia Sea Cooperation Body, we will focus on key areas such as port green development, shipping emission reduction and marine biodiversity protection. In terms of infrastructure, pollution reduction and carbon reduction, scientific and technological cooperation, talent exchange and training, and international convention implementation, we will promote the green development of maritime interconnection in the BRI, form and improve the regional cooperation mechanism for the normalization of marine ecological environment governance along the BRI, and contribute to the green and high-quality development of the BRI.

1. Form a normalized regional cooperation mechanism for marine ecological environment governance, jointly address the marine ecological environment problems in the coastal areas of the BRI, and promote regional sustainable development.

2. Promote scientific and technological exchanges and cooperation on marine ecological environment in coastal countries of the BRI, especially in key areas such as port green development, shipping emission reduction and marine biodiversity protection, and strengthen mutual visits of scientific researchers, co-construction of scientific research bases and cooperation in scientific research projects, so as to enhance the scientific research capability and level of the co-constructed national marine ecological environment, and improve the management capability and governance level of the co-constructed national marine ecological environment.

3. Promote pragmatic cooperation in key areas through existing cooperation platforms, improve the efficiency and quality of cooperation, form a batch of green cooperation projects with demonstration functions, and share good practices for building green development of maritime interconnection.

2. Suggestions for the BRI Marine Interconnection Green Development

2.1 Policy Recommendations for the Green Ports Development

Clean, low-carbon and high-quality development is the trend of the times and the foundation of sustainable development of the Maritime Silk Road Economic Belt. Developing green ports is the basic requirement of the green BRI.

2.1.1 Give full play to the main responsibility of the market, and strengthen accurate pollution control, scientific pollution control and pollution control according to law.

Port and shipping operators are the main body of green port construction and development. Enterprises should hold high the banner of developing green ports and set a green and low-carbon development model for the green BRI. To strengthen the construction of port environmental protection infrastructure, increase the proportion of clean energy, enhance the risk prevention ability, promote the multimodal transport of public iron and water, build the ship air pollution emission control zone and other institutional systems, and promote the construction of green port governance system and modernization of governance capacity.

2.1.2 Strengthen the linkage between ports and hinterland, and enhance international cooperation and exchanges

Promote the transformation and upgrading of hinterland cities with green development of ports, promote the green and low-carbon development of ports with high-quality development of hinterland cities, promote the integration of ports and cities, and promote the coordinated development of port and shipping industry with cities or park industries, so as to share green development achievements. Promote standard docking, strengthen facility connectivity, and promote the integrated development of the BRI green port on the basis of diversified development. Strengthen policy incentives, increase financial input, and vigorously support the development of green transportation.

2.1.3 Accelerate the formulation and revision of standards and specifications, and

promote the standardization of energy conservation and emission reduction management

In the construction of green port, we should give full play to the main role of port enterprises in transportation energy-saving emission reduction standards, give full play to the enthusiasm of port enterprises, encourage port enterprises to formulate port construction plans and adopt advanced standards, participate in or undertake the revision of national and industrial energy-saving emission reduction standards, actively implement green port construction, and improve the comprehensive competitiveness of port enterprises.

2.2 Policy Recommendations for the Green Shipping Development

2.2.1 Establishing a monitoring, reporting, and verification (MRV) framework for international shipping within BRI

A comprehensive and functional MRV system is an indispensable part of ensuring progress of GHG mitigation measures. The monitoring of implementation progress aims at not only estimating real-world impact on GHG emission reduction, but also the realization of government action plans in implementing policy measures and its vision.This study has reviewed national and supranational policy measures in BRI countries and concluded that the environmental governance of the BRI still lacks an effective monitoring and evaluation framework to ensure the realization of its stated vision. A detailed monitoring plan, including division of responsibilities among relevant stakeholders, is needed for international shipping within BRI.

Therefore, we suggest a MRV framework should be jointly implemented among BRI member countries along with mechanisms to monitor, report, verify and share the data related to GHG mitigation programs. All BRI member countries, as well as 32 international organizations that have signed cooperation documents with China, can use a joint data-sharing platform. The data collected can be leveraged to gather support for environmental financing of green shipping projects within BRI countries that have higher GHG mitigation potentials.

2.2.2 Setting up technical cooperation and joint research program for assessing the potentials for zero-carbon alternative fuel production.

The development of low-carbon alternative fuels that can meet decarbonization targets and are economically viable for the shipping sector is a crucial long-term carbon reduction strategy for the IMO. In order to select fuel types that offer the best opportunities for zero-emission shipping for different countries, it is critical to understand the full life-cycle emissions and benefits and costs of various low/zero-emission fuels and propulsion technologies. Production costs and the carbon intensity of alternative fuels such as biofuels, ammonia, and hydrogen are varied and typically depend on the characteristics of the countries that produce them. Specifically, the potentials for each country to produce zero-carbon fuels will depend on factors such as: 1) Available natural resources and capacity to produce renewable energy for low/zero carbon fuels. 2) Levels of access to knowledge and production technologies. 3) Available transport and storage infrastructure. 4) Infrastructure of energy supply.5) Energy needs of each country.6) Global policy and regulation incentives.

A full life-cycle assessment of various low/zero-emission fuels and an analysis of the supply and demand of low/zero-emission fuels, taking into account the specific conditions of the BRI countries, is needed. This assessment can be done in a joint research program within BRI and specifically aimed to improve the economic viability of these zero-emission fuels for BRI countries. The output of the study will form a valuable input and lay the foundation to develop a long-term decarbonization strategy for the maritime transport within BRI.

2.2.3 Strengthening the research and application of low-carbon port technologies to

promote the coordinated development of green port and green shipping

Ships and ports are two elements of maritime transport, with ships being the primary means of transport and ports providing the transport base. Therefore, the development of green shipping can not be achieved without ports support, and port authorities can also adopt technologies that can facilitate reduction of GHG emissions at ports. Two examples of these technologies that have been widely adopted are onshore power supply (OPS) and ship-port interface.

Ports need to be equipped with OPS for allowing ships to turn off their engines and connect to the electricity grid to power ships. To stimulate the uptake of this technology, governments can consider exemption of energy tax for OPS and port fee reductions for ships using OPS. Ship-port interface is a platform for data interconnection and communication between ships and ports. Using this technology, ships can update their routes, destinations, loading capacity and expected arrival time in advance. Based on this information, ports can make suitable adjustments and scheduling of resources and equipment to improve the efficiency of terminals and reduce the turnaround time of ships at port. Specifically, ports can update berth reservations and usage in real time, and ships can plan their routes and sailing time reasonably and avoid unnecessary delays, detours, queues and bunching. This improved facility utilization and coordination will lead to emission reduction in ships and ports. Suggest BRI countries strengthen the research and application of low-carbon port technologies to promote the coordinated development of green port and green shipping.

2.2.4 Develop an green shipping incentive program and explore carbon pricing mechanisms

BRI Countries could consider the incentives for ships that have excellent operational carbon intensity ratings. The carbon intensity rating could be linked to the annual operational carbon intensity index (CII) and the CII rating scheme proposed by the IMO. Reward for ships with excellent ratings or develop tiered incentives to encourage ships to obtain excellent ratings and promote more ships with excellent carbon intensity to work on the Maritime Silk Road. In addition, attempts can be made to explore a carbon pricing cooperation mechanism for international shipping emissions reduction, and to promote more efficient and cleaner ship and the large-scale use of alternative fuels through this low-cost market means of emissions reduction.

2.3 Policy Recommendations for Marine Biodiversity Protection

Biodiversity conservation cooperation is an important part of the high-quality BRI development. Under the BRI, actively promoting the construction of the green BRI, building a green consensus among countries, deepening cooperation in the field of marine biodiversity research and protection, and carrying out regional cooperation on marine biodiversity with relevant countries and regions will provide good opportunities for the protection of the marine biodiversity within and along the BRI countries and even in the world.

2.3.1 Promote the establishment of bilateral and multilateral cooperation mechanisms for marine biodiversity conservation

Through high-level diplomacy, scientific research cooperation, personnel exchanges, investment and financing, etc., we will continue to expand cooperation between China and other countries in the field of marine ecological environment protection, establish a stable bilateral and multilateral cooperation mechanism for marine biodiversity protection, and gradually enhance the capacity and level of the co-construction countries in marine biodiversity protection policies and strategies. Relying on the work foundation of China-ASEAN in ecological environment and biodiversity protection, we will enhance the marine background, and deepen the marine biodiversity protection cooperation contents such as coastal wetland ecological protection and management, mangrove protection, elimination of alien species invasion, and management of marine nature reserves. Exchange and discuss the current situation, objectives and technologies of marine biodiversity conservation with other maritime countries along the BRI, and expand the breadth and depth of cooperation in marine biodiversity conservation in the form of projects.

2.3.2 Strengthen cross-border biodiversity research cooperation

Strengthen inter-regional cooperation in marine biodiversity research, rely on the existing bilateral and multilateral platforms and cooperation mechanisms, focus on the field of marine biodiversity, and carry out cross-regional major scientific research and joint scientific investigation on the protection of typical marine ecosystems and the construction of nature reserves. Focusing on China-ASEAN regional cooperation on biodiversity conservation in the South China Sea, we will carry out joint investigation and exchange activities on ecosystem health protection technologies for coral, flagship species, migratory birds, mangroves, seagrass beds and other ecosystems and typical protected animals. Strengthen the flow and training of talents in the field of marine biodiversity, carry out international training, exchange and cooperation on personnel skills around marine biodiversity resource survey, marine biodiversity value assessment, biodiversity compliance, environmental laws and policies, etc., sum up the technologies, experiences, achievements and existing problems of various countries in the above-mentioned fields, and gradually enhance the capacity of the co-construction countries in the talent construction and scientific research of marine biodiversity protection.

2.3.3 Expand investment and financing channels for marine biodiversity conservation

Financial support is the basis for countries to carry out marine biodiversity conservation work. Analyze the financing demand and supply potential of marine biodiversity conservation, and evaluate the effects of existing environmental strategies, green financial practices and financial support. Expand investment and financing channels for regional marine biodiversity protection through technical seminars and other means, and enhance the ability of regional cooperation and support. Support regional seminars and exchanges on financing channels and financing capacity building for estuaries, coastal zones and fishery resources management, and conduct discussions and exchanges through experience sharing, field reconnaissance, and fund utilization schemes, so as to attract more green finance to marine biodiversity conservation projects, expand investment and financing channels in the BRI countries, and enhance support capacity.

2.3.4 Pay close attention to the progress of global marine biodiversity conservation

Enhance the capacity of the co-construction countries in the implementation of the *Convention on Biological Diversity*, actively track the relevant work on ecologically or biologically significant marine areas (EBAS) under the framework of the *Convention on Biological Diversity*, prepare the EBAS regional work report in the East Asia Sea, and start the comprehensive marine survey to identify and identify the ecological and biological elements of EBAS as soon as possible in key interest areas. It is suggested to carry out biodiversity surveys in key sea areas such as the Northwest Pacific Ocean, the Philippine Sea and the Northwest Indian Ocean, carry out research on the technical methods of selecting high seas protected areas, increase the reserve of think tanks, and step up the expansion of the reserve of marine genes and genetic resources, so as to provide scientific basis for the negotiation of benefit sharing system.

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