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Current challenges and future recommendations for green shipping

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CURRENT CHALLENGES AND FUTURE RECOMMENDATIONS FOR GREEN SHIPPING

By

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature: …………………………..

Date: …………………………..

Supervised by: …………………………..

Supervisor's affiliation: …………………………..

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The time that we studied together in the MSEM program passed quickly. As a non-maritime specialty staff member of the maritime safety administration, through this year's study, I have a deeper understanding of shipping industry, a more detailed understanding of maritime supervision, the emergence and development of international conventions behind maritime supervision, and a comprehensive understanding of the logic behind maritime supervision.

Because of the covid-19 epidemic, some of our courses were completed remotely through zoom, and some classmates just met in a hurry. Although some courses were online, each course has various forms. Although we didn't see each other very often, we have forged a deep friendship in teamwork and offline practice activities.

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hope this imperfect paper can make him feel proud of me.

ABSTRACT

Title of Dissertation: **Current Challenges and Future Recommendations for Green Shipping**

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abstract

Nowadays, shipping carbon reduction and shipping sulfur and nitrogen oxides emission reduction have become another hot spot after preventing ships from polluting sea waters. In terms of shipping carbon reduction, IMO has formulated a series of carbon reduction goals according to the relevant requirements of the UN and the actual situation of the industry. Some developed countries have formulated regional carbon reduction policies, such as the EU Carbon Taxes. In terms of sulfur and nitrogen oxides reduction, IMO has developed relevant requirements. And some emission reduction methods have already been widely tried in the whole industry. This paper reviews the previous research on shipping emission reduction, studies the IMO's overall strategy and specific requirements for shipping emission reduction, including EEDI and SEEMP which are indexes to measure ship emissions. This paper introduces the relevant requirements of various international conventions for sulfur and nitrogen emissions from ships, and introduces the installation of desulfurization towers, the use of SCR system and the use of LNG fuel on ships. This paper analyzes the challenges faced by green shipping, and tries to give the suggestions for the future development of green shipping.

KEYWORDS: Carbon Reduction, Sulfur and Nitrogen Control, Anti-pollution, Shipping

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

LNG	Liquefied Natural Gas
IMO	International Maritime Organization
GHG	Greenhouse Gas
EU	European Union
UN	United Nations
ECA	Emission Control Area
MEPC	Marine Environmental Protection Committee
SEEMP	Ship Energy Efficiency Management Plan
EEDI	Energy Efficiency Design Index

CHAPTER 1 BACKGROUND INFORMATION

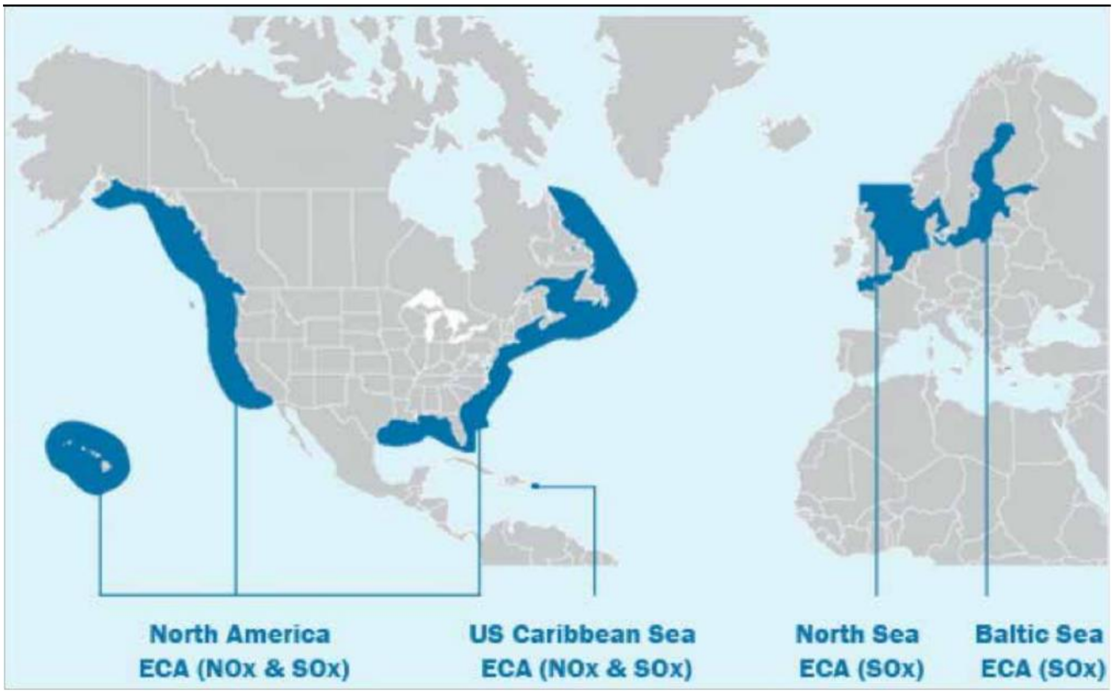
1.1 The Problem Statement

Since the beginning of industrialization, mankind has been transforming nature. The burning of large amounts of fossil fuels has accelerated the modernization of human society and global integration, while emitting large amounts of greenhouse gases and harmful gases containing S, N and other harmful elements. The large amount of greenhouse gases has caused serious environmental problems such as global warming and sea level rise. The emission of harmful gases has also brought great impact on the atmospheric environment and human health. (Wang Andong, 2020)

Shipping accounts for more than 90% of the global transportation industry. Because of its high volume and low price, some materials, such as iron ore and grains, which have a significant impact on the world economy are often transported by sea. Compared with land-based industries, the energy consumption per unit, the GHG emissions per unit and emissions of gases containing sulfur and nitrogen elements are not so high in the shipping industry. However, because of its large total cargo volume, the annual pollution caused by ships to the sea and atmosphere cannot be ignored. According to IMO data, shipping industry emitted 796 million tons of carbon dioxide in 2020, accounting for about 2.2% of global carbon emissions. Marine Benchmark, a maritime data provider, said that the global shipping carbon emissions decreased by 1% in 2020 due to a small decline in global shipping volume affected by the COVID-19 outbreak. Several shipping agencies, including Clarkson and Simpson Spence Young, have already made forecasts for global carbon emissions in 2021, and they predict that shipping will emit higher carbon emissions in 2021 than that in 2019, the pre-epidemic year. Which was caused by easing of the epidemic prevention and control policies in the world's major economies, the increased speed on certain shipping segments and the port congestion. Carbon emissions from shipping are projected to be 840 million tons in 2021. In terms of reducing harmful emissions, the IMO mandates that all ocean-going vessels must reduce the sulfur content standard in fuel oil from 3.5% to 0.5% in 2020. (Liu Xiancheng, 2012)

In the face of the huge carbon emissions brought by the shipping industry, IMO began to focus on shipping carbon reduction efforts as early as in 1997. After the adoption of the Kyoto Protocol, IMO formally launched the discussion of international shipping GHG emission reduction issues. In 2003, the Marine Environmental Protection Committee (MEPC) under IMO established and supervised the international shipping GHG emission reduction mechanism, and in 2011, it was included in MARPOL ANNEX VI. In the MEPC meeting 2016, IMO adopted the ship GHG emission reduction Comprehensive strategy roadmap, initially determined the implementation schedule of IMO three-step strategy. In terms of ship sulfur reduction, IMO firstly mentioned the establishment of sulfur emission control area (ECA region) when revising the MARPOL Convention in 2005. This regulation is to regulate the sulfur content of fuel oil used by ships in the region. IMO revised and strict requirements on the sulfur content of fuel oil used by ships twice in 2008 and 2016. The United Nations also paid attention to the adverse impact of GHG emissions on global climate change at an early stage, and adopted the United Nations Framework Convention on Climate Change in 1992, the Kyoto Protocol in 1997 and the Paris Agreement in 2016 respectively. (Wu, Ruolan, 2019)These three documents have become the legal basis for the global response to climate change. Some developed regions and countries have introduced corresponding policies to climate change, and the EU has even introduced a carbon tax policy and published a carbon emission price list for the shipping industry. The United States has introduced specific emission regulations for some ports. In 2002, China stated that it would achieve its carbon peak target by 2030 and its carbon neutrality target by 2060. (Ma Xuefei, 2020)

Figure 1 Emission Control Areas

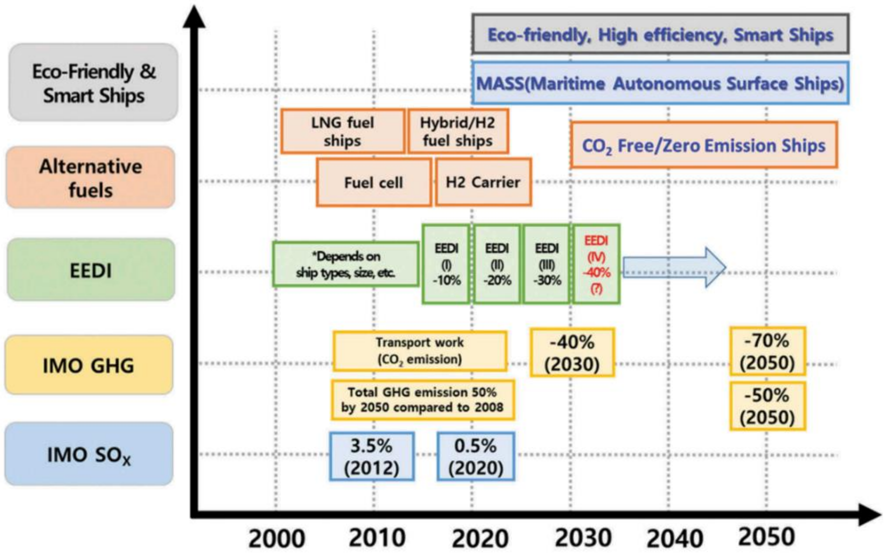


Emissions of secondary PM emissions are indirectly regulated through the SOx limits enforced in the SOx ECAs.

Source: IMO's Research, (2020)

These countries and international organizations have introduced conventions and annexes based on their carbon reduction pathways and targets. These conventions have contributed to the reduction of industry-wide carbon emissions to a certain extent. But the current pace of carbon reduction efforts is far from sufficient for the IMO's designated mid-term goal of carbon reduction. The goal is to achieve at least a 40% reduction in carbon emissions intensity from ships by 2030 compared to 2008, and a 50% reduction in total GHG emissions by 2050, and about a 85% reduction in CO2 emissions from individual ships compared to 2008. Other further carbon reduction measures are needed to ensure that the above tasks are accomplished. The global COVID-19 epidemic is currently underway and its impact on carbon reduction in the shipping industry is still unclear. The United States, a major world economy and shipping power, withdrew from the Paris Agreement in 2020, the impact of its carbon reduction efforts on global shipping carbon reduction is still difficult to predict. In addition, most of the ships are sailing internationally, and the registered nationality of ships and the nationality of ship owners and operators may be different. The attribution of carbon emissions from international ships, the controversy of ship construction and operation emissions, and how to implement effective measures to reduce carbon emissions from shipping worldwide are still problems worth studying. At the same time, in the process of carbon and sulfur reduction in shipping, it is also worth considering how to help developing countries with technical difficulties to accomplish the carbon reduction target without reducing the competitiveness of shipping due to additional investment. (Pan, Yinru, 2021)

Figure 2 IMO's Overall Emission Reduction Strategy



Source: IMO's Research, (2022)

1.2 Literature Review

In terms of government policy orientation: The United Nations has issued three documents, namely the United Nations Framework Convention on Climate Change, the Kyoto Protocol and the Paris Agreement, to cope with climate warming. And these three documents have become the programmatic documents for the global solution of climate change. But there are no corresponding specific requirements for shipping industry in the documents. The MEPC meeting under IMO has made the requirement of reduction of carbon emissions and harmful emissions containing sulfur and nitrogen by shipping through the MARPOL Convention. IMO's efforts are to achieve a 40% reduction in the carbon intensity of ships by 2030 and a 50% reduction in the total GHG emissions of shipping by 2050. In 2011, IMO included the ship energy consumption rules in MARPOL 73/78 Annex VI, requiring ship manufacturers to follow this guideline to calculate the ship's Energy Efficiency Design Index (EEDI) for new ships. In the face of increasingly stringent requirements for carbon reduction in shipping, the transportation departments of major shipping countries have issued corresponding documents. The U.S. Department of Transportation has formulated "the U.S. Transportation Strategic Plan". Japan has released the "Outline of New Integrated Logistics Governance". And the EU has released the white paper "To Transport Strategy - Time to Decide". All the documents above have influenced global shipping emission reduction to a certain extent.

In terms of carbon trading market orientation: Litman T. analyzed the collection and redistribution process of the first carbon tax in North America. Joseph K. et al. studied the trading mechanism and effects of carbon trading in the EU, and pointed out that the parts of the EU carbon tax trading system are worth learning. Perdan S. et al. analyzed and compared the carbon trading mechanisms in the EU, the US, New Zealand and Tokyo, and pointed out that the future carbon trading will be globalization and will contain more GHG. Zhang Y. et al. summarized the operation mechanism and economic impact of carbon trading in the EU, and predicted the development trend of carbon trading in the EU. Fu Huishu proposed that China should establish a carbon tax collection system according to national conditions, and should pay attention to the relationship between carbon tax and the original taxes to avoid double taxation. (Hou Xiaoming,2019)

In terms of ship operation: Haakon Lindstad et al. studied the impact of low speed on fleet carbon emissions and operating costs, and put the selected representative ship types into the model. The results show that reducing speed can effectively reduce fleet carbon emissions. Williams. E et al. analyzed the fleet operations of shipping companies and proposed solutions to reduce fleet carbon emissions. Kontovas C calculated the fuel consumption and CO2 emissions of ships during sailing and port calls, and proposed that by strengthening dispatching and cooperation with port side. Ships can reduce the berthing operation time and appropriately slow down the speed, so as to realize ship carbon reduction while ensuring economic benefits. M.S. Eide developed a whole set of emission reduction solutions for container fleet, bulk carrier fleet and tanker fleet, meanwhile, he paid attention to the non-carbon pollutants that should also be given full attention. (Zhu Xiao, 2018)

In terms of advanced ship technology: Jonathan Childs proposed three ways to improve ship energy consumption by installing electric propulsion systems, upgrading ship core systems and adopting streamlined hulls. Cariou P. studied the possibility of achieving ship emission reduction by reducing ship speed, while considering the impact of freight and fuel prices on achieving this goal. He concluded that the strategy is feasible when the fuel price is maintained at 350-400 USD/ton. Li Sheng calculated the fuel consumption and GHG emissions of ships with different power main engines at different speeds and gave relevant emission reduction suggestions. Zheng Qinggong established a mathematical model taking into account the ship type, ship age and hull structure, and made a comprehensive analysis of the whole process of ship shipping. He studied the influence of ship type, ship age and hull structure on the carbon reduction of shipping.

In terms of the impact of COVID-19 epidemic on shipping: Wang Jingyan studied the impact of COVID-19 epidemic on maritime freight, shipping company operations and crew, and found that the current health quarantine policy would increase the time of ships arriving at port and staying at anchor, which would cause an increase in ship emissions. Wan Chengpeng et al. studied the routes departing from China of 50 major carriers, including Maersk, COSCO Shipping, and Duffy, and concluded that the epidemic has caused low ship loading rates and reduced loading and unloading efficiency at ports in various countries. This resulted in the increased transportation costs per unit of cargo and the increased carbon emissions per unit of cargo. Kitack Lim, Secretary General of IMO, in IMO’s fourth study on maritime GHG emissions in 2020 stated that it is too early to quantitatively assess the impact of the COVID-19 epidemic on GHG emissions reduction from shipping, but the epidemic still has an uncertain impact on GHG reduction efforts.

1.3 Comments on Literature and Innovations

Carbon reduction in shipping and reduction of harmful emissions containing elements such as sulfur and nitrogen are currently hot topics in the industry. Many domestic and international studies have focused on this area. In terms of government policies, almost all countries and international organizations have introduced corresponding shipping emission reduction policies to promote emission reduction. However, the scope of application of these policies is different and the strictness of these policies is different. The current researches are mostly focused on the analysis of a certain policy, and there are few cross-sectional comparisons between policies. In terms of carbon trading market orientation, the current researches on the EU carbon tax are often from a single perspective, mostly from the jurisdictional and economic perspectives of the carbon tax. There is rarely a comprehensive and holistic analysis of the EU carbon tax. In terms of ship operation, the current researches are mostly based on the specific operation mechanism of fleet, but there is less exploration on the development mode of low-carbon integrated logistics service for shipping enterprises. Although we clearly know that COVID-19 epidemic will have an impact on carbon reduction of shipping, the quantitative analysis of its impact on carbon reduction of shipping is still relatively rare and worthy of in-depth study. (Yao Qian, 2019)

Based on the above research background, this paper attempts to make the following innovative assertions by summarizing and sorting out the existing literature and combining it with the actual situation of shipping during the COVID-19 epidemic.

First of all, the policies of various countries and international organizations to reduce carbon and harmful gas emissions from ships were mostly formulated before the COVID-19 epidemic, taking into account economic and technical factors, without taking into account the impact of the epidemic on the emission reduction of ships. This paper attempts to explore the impact of the epidemic on international shipping today, especially on green shipping, and tries to find solutions to overcome the adverse effects of the epidemic. This is necessary at a time when the development of the global epidemic is still uncertain and carbon reduction efforts continue to advance. (Wang, Lin, 2022)

Secondly, in the current researches on carbon reduction of shipping companies, experts and scholars mostly focus on how to reduce carbon emissions and harmful gas emissions by reducing speed and by optimizing operation methods based on the existing fleet operation methods. This paper attempts to explore how shipping companies can achieve transformation and upgrading to build a low-carbon integrated logistics service development model during the epidemic. (Feng Hongyue& Yang Lu, 2020)

Thirdly, this paper tries to compare the EU carbon trading mechanism with the carbon reduction instruments of other countries and regions horizontally by using the comparative research method to understand the advantages and disadvantages of their mechanisms. At the same time, the empirical research method is used to combine the actual characteristics of some developing countries to make reasonable and feasible suggestions for their future carbon reduction efforts, especially under the influence of the epidemic and the relative financial constraints of each country.

1.4 Research Methods

This paper mainly adopts literature analysis method, inductive analysis method, comparative study method and empirical study method to analyze and research on the future carbon reduction work of international shipping in a period of time, especially under the influence of COVID-19 epidemic, and try to make suggestions on the future carbon reduction work of shipping.

The first in line is that literature analysis method. With the help of the university library, domestic and international web databases, IMO official website, websites of various maritime data analysis and websites of transportation departments of major shipping countries and regions, such as US and EU, and the textbooks, the authors have obtained the latest world shipping emission reduction process and advanced practices of major shipping countries and regions today as the theoretical basis of this paper. The second is that the inductive analysis method. The authors collected and organized the related measures of carbon reduction and reduction of harmful gas emissions containing sulfur, nitrogen and other elements from ships at home and abroad, and extracted their common problems. The next is the comparative study method. Because IMO's requirements for carbon reduction in shipping are mostly framework requirements, individual countries and regions often adopt different emission reduction paths due to different levels of technology and scale of shipping. By comparing the differences in measures among different countries, the strengths and weaknesses of each country's carbon reduction work measures can be found, so that future work can be better improved. The last but not the least is that empirical research. In the last of this paper, mainly through the method of empirical research, reasonable suggestions are made on how to improve the mechanism of carbon reduction work in shipping in the future and accomplish the carbon reduction target as planned, especially in the context of COVID-19 epidemic.

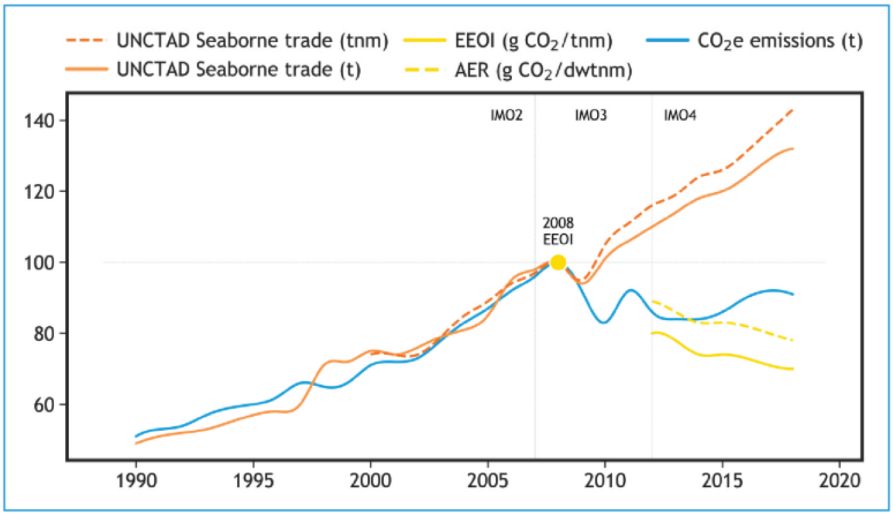
CHAPTER 2. REDUCTION OF CARBON AND HARMFUL GASES CONTAINING SULFUR AND NITROGEN OXIDES IN SHIPPING

2.1 Definition of Greenhouse Gases（GHG）

GHG refers to some gases that can absorb long wave radiation reflected by the ground and reemit radiation. These gases will make the earth's surface warmer, which is similar to the role of greenhouse in intercepting solar radiation and heating the air in greenhouse. We call the phenomenon that GHG make the earth warmer as the greenhouse effect. The Kyoto Protocol stipulates six kinds of greenhouse gases, and they are: CO_2、CH_4、N_2O、HFCs、PFCs and SF6. In the global GHG emission reduction work, the contribution of CO_2 to the rise of global temperature is the largest, accounting for about 25%, which makes the reduction of CO_2 become the main goal of global GHG emission reduction.

Figure 3 GHG Emission from the International Shipping

Inventory of GHG Emissions from International Shipping 2012-2018



Source: IMO's Research, (2020)

2.2 Time Limit for the Requirements of GHG Emission Reduction in Shipping

In addition to the emission reduction requirements from the United Nations environmental protection conventions and requirements from national shipping management departments mentioned above. At present, the most urgent thing for the shipping industry in terms of GHG emission reduction is how to meet the emission reduction requirements in two key time (2030 and 2050) nodes set by IMO through the comprehensive application of various means. In April 2018, IMO's MEPC held its 72nd session in London. MEPC adopted the IMO preliminary strategy for greenhouse gas emission reduction with MEPC Resolution 304 (72). This strategy is the overall arrangement made by IMO for GHG emission reduction in the shipping industry in accordance with the relevant emission reduction targets specified in the Paris Agreement.

Table 1 IMO's Actions and Programs to Reduction

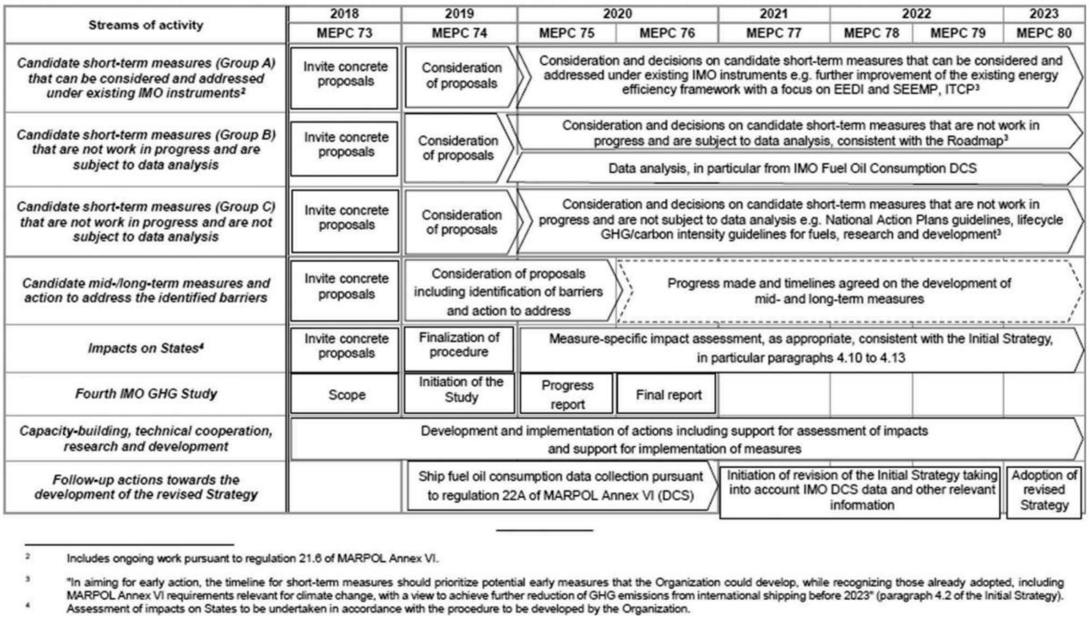


Figure 1. Follow-up actions & programs (IMO MEPC73 2018).

Source: IMO's Research, (2021)

This strategy puts forward three basic requirements for reducing GHG emissions from international shipping. The first requirement is to make EEDI to play a much more important role in shipping emission reduction, to evaluate each stage of EEDI mandatory requirements, to judge the energy consumption efficiency of each ship type in each stage and determine which type should be improved according to the evaluation. The second in line is that the strategy puts forward the requirements for carbon intensity of international shipping. The strategy requires that the CO_2 emission intensity per unit of international shipping in 2030 will be 40% lower than that in 2008. The CO_2 emission intensity per unit of international shipping in 2050 will be 70% lower than that in 2008. According to IMO data, the total tonnage of CO_2 emitted by international shipping in 2008 was 921 million tons. The last requirement is that IMO requires that the total GHG emissions from international shipping should reach the peak and decrease as soon as possible. According to IMO data, the total GHG (including CO_2, CH_2 and N_2O) emitted by the international shipping industry in 2008 was 940 million tons. (An W&Guo P, 2021)

During the implementation of IMO's preliminary strategy for GHG emission reduction, we can divide the emission reduction measures into short-term measures, medium-term measures and long-term measures according to the time arrangement of measures. The relevant measures from now to 2023 can be called short-term measures, mainly including: making EEDI a much more important role in the industry, improving the energy efficiency of newly-built and existing ships, encouraging ship speed reduction operation, promoting fleet emission reduction, developing alternative fuels and low-carbon fuels for ships, and conducting the fourth IMO GHG research. The policies from 2023 to 2030 can be regarded as medium-term policies, including promoting the use of low-carbon, zero carbon fuels or alternative fuels for ships, making the EEDI a much more important role in the operation of newly-built ships and existing ships, establishing a new emission reduction mechanism including market mechanism, and establishing an experience exchange and feedback mechanism in carbon reduction. The long-term measures are the measures finally determined and agreed after 2030, including continuing to develop and promote zero carbon fuels and creating new emission reduction mechanisms. In addition, IMO's MEPC will adopt the revised IMO GHG emission reduction strategy in 2023.

Figure 4 Emission Pathway

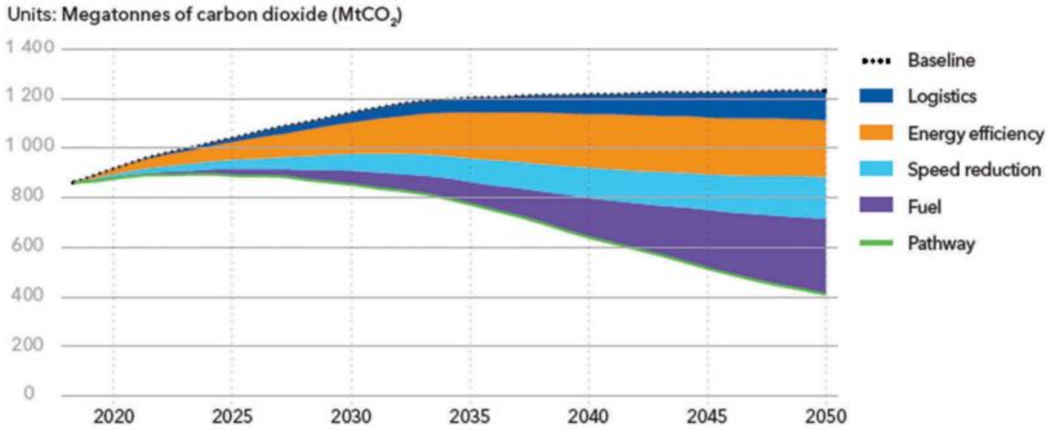


Figure 3. Emission pathway 2015–2030 (International shipping) (DNV-GL 2019).

Source: IMO's Research, (2021)

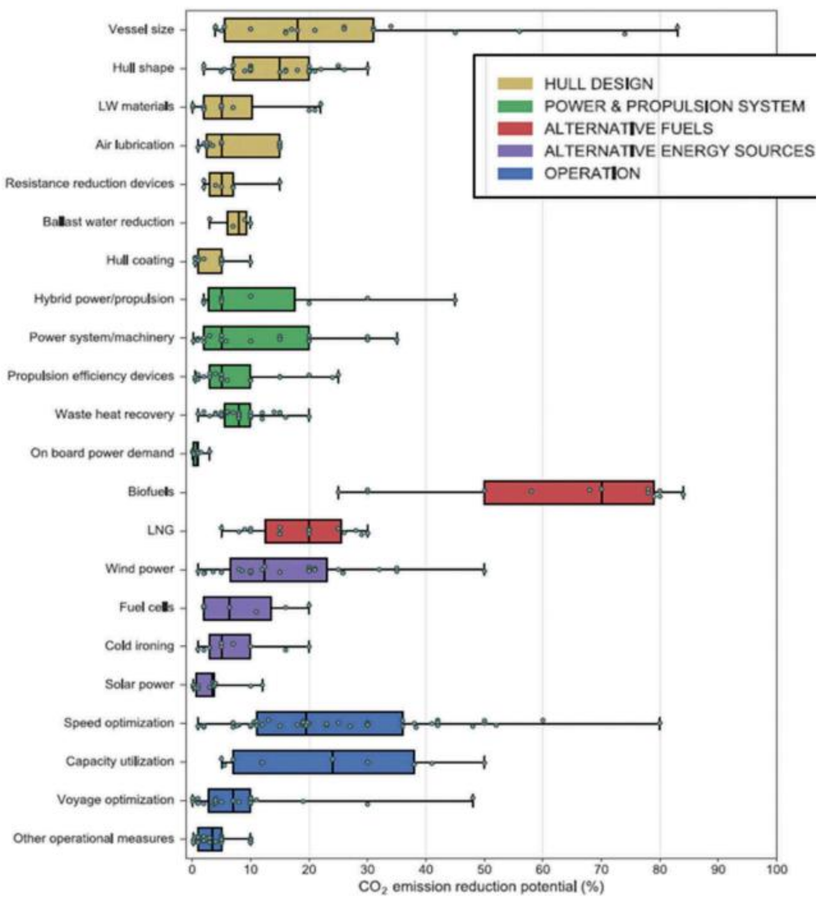
2.3 Impacts of IMO Preliminary GHG Emission Reduction Strategy

The introduction of IMO's preliminary GHG emission reduction strategy reflects IMO's determination to reduce GHG emissions in the global shipping industry as a specialized organization responsible for maritime safety and environment of the United Nations. It will also promote the transformation and upgrading of the industry and scientific and technological progress in shipping, promote the reduction of shipping carbon emissions, and have a far-reaching impact on the shipping industry. In the process of formulating this strategy, IMO has taken into account its mandatory and effective characteristics for all ships, which will bring practical implementation difficulties to some developing countries. Therefore, this strategy accepts the principle of "common but differentiated responsibilities" and respective capabilities in the United Nations Convention on Climate Change, the Kyoto Protocol and the Paris Agreement. In the preparing of strategy, IMO also took into account the impact of the strategy on IMO's memberships, especially the least developed countries and small island developing states.

2.3.1 The Impact of the Strategy on Shipping, Shipbuilding and Fuel Supply Enterprises

However, in the implementation of the strategy, the impact of the following problems cannot be ignored. The first in line is that higher standards have brought higher requirements to the operation of shipbuilding industry and shipping enterprises. In order to achieve the goals set by IMO within the specified time, the shipbuilding industry has to significantly increase scientific and technological investment to promote the upgrading of ship technology, such as optimizing hull design, developing kinetic energy recovery devices, etc. Shipping enterprises have to increase investment to study how to promote fleet emission reduction, upgrade fleet operation mode and find the best speed of the fleet. Fuel supply enterprises have to increase investment to develop low-carbon and zero carbon fuel, and look for alternative fuel for ships. We all know that the shipping industry needs a lot of capital and technical investment in reducing GHG emissions, which will lead to the rise of international shipping costs and international shipping freight rates, which reduces the competitiveness of shipping in various modes of transportation to a certain extent. At the same time, compared with developed countries, developing countries have poor economic foundation and weak technical capacity. Both shipbuilding and shipping enterprises are often at the bottom of the industry and occupy the market with their relatively low prices. If the actual situation of each country is not fully taken into account in the process of policy implementation. This will make some developing countries in a disadvantageous position in the competition due to the policy of reducing GHG emissions, and even lose their share in the international shipping market, thus aggravating the monopoly of developed countries on the shipping market.

Figure 5 Emission Reduction Potential of Different Emission Reduction Methods



Source: IMO's Research, (2022)

2.3.2 The Impact of the Strategy on Emission Reduction Policies of Different Countries

The second is the impact of IMO's preliminary GHG emission reduction strategy on domestic GHG emission reduction policies. As we all know, IMO's preliminary GHG emission reduction strategy is a mandatory convention in the shipping industry. Its implementation will inevitably drive the Legislative Transformation of IMO Member States' domestic regulations. In order to achieve the goal of reducing GHG emissions, different countries often adopt different strategies. For example, EU countries reduce GHG emissions through market methods such as carbon tax, Japan implements a voluntary carbon emission trading system, and the United States promotes ship GHG emission reduction through government support. These policies and strategies are different. But in shipping which is one of the industries with a high degree of internationalization, the policies will more or less affect the ships of other countries in addition to promoting the GHG emission reduction of domestic ships. For example, the EU imposes a carbon tax on ships coming to the EU. Because of the mutual influence of national policies and other reasons, it is worth thinking about how to make the shipping emission reduction policies of various countries agree with each other while meeting the relevant requirements of IMO, and do not have an adverse impact on the emission reduction policies of other countries.

2.3.3 The Impact of the Strategy on Ship Development and Fleet Operation

Third, the research and development of high-efficiency ships and the efficient operation of the fleet put forward higher requirements for the ability of practitioners. Because the IMO preliminary GHG emission reduction strategy is a preliminary solution proposed by IMO for the problems faced by shipping at present, and the requirements for shipping related technologies are relatively basic. Compared with the short-term measures, the medium-term and long-term further measures in the preliminary strategy are more detailed and more strict, which puts forward higher requirements for ship designers and builders and the operators of shipping companies. This requires ship designers and builders to better grasp the development direction and measures of ship energy saving, and requires the operators of shipping companies to rely on their own knowledge reserves to continuously optimize the fleet operation plan and help the fleet choose the best speed. At the same time, maritime practitioners should always track and enhance their understanding of IMO's relevant maritime emission reduction policies, so as to fully and accurately meet the latest requirements of IMO.

2.4 Origins of Ship Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP)

2.4.1 Origin of Ship Energy Efficiency Design Index (EEDI)

In the context of the continuous promotion of emission reduction in the shipping industry, the 56th IMO's MEPC meeting discussed that the current total number of shipping ships in the world is large, the ship conditions are different, and the intensity of shipping emission reduction in various countries is also different. It is unrealistic for IMO to launch a complete emission reduction scheme for all ships currently in operation, while taking into account the interests of all contracting parties. Therefore, MEPC focuses on unfinished ships and tries to develop a new work index to measure the energy-saving level, ship type and engine efficiency of newly built ships. At its 57th meeting, MEPC absorbed the proposal of many shipping enterprises to formulate "Mandatory new ship carbon dioxide design index" and decided to establish three working modules, namely "New ship carbon dioxide design index", "Operation carbon dioxide emission index" and "Market operation". At its 58th meeting, MEPC changed the "New ship carbon dioxide design index" to "Ship energy efficiency design index (EEDI)" to show its concern about improving energy efficiency in the design and construction of new ships. At the 59th meeting of MEPC, EEDI was further improved and sent to all countries in the form of circular letter, and its voluntary implementation was encouraged. It was not until the 62nd MEPC meeting held by IMO in London in 2011 that the role of EEDI in shipping emission reduction was formally established with the amendment to MARPOL Annex VI on ship energy efficiency.

2.4.2 Origin of Ship Energy Efficiency Management Plan (SEEMP)

At the same time, IMO included the operational emission reduction measures SEEMP as a mandatory requirement in Annex VI of MARPOL for the first time at the 62nd meeting of MEPC, and required the applicable ships to hold the SEEMP approved by the competent authority or organization. In 2016, MEPC resolution 278 (70) adopted the amendment to Annex VI of MARPOL 73 / 78, which requires that a data collection mechanism for ship fuel consumption be added to the ship energy efficiency rules, and ships should submit an annual report on ship fuel consumption to the flag state or its authorized and recognized organization after the end of each reporting year. At the 2018 IMO meeting, the expert group proposed to achieve the goal of "zero emission" of shipping as soon as possible in this century. It is hoped that the carbon emission intensity of shipping can be reduced 40% by 2030 and 70% by 2050. The realization of these two goals is inseparable from the help of EEDI and SEEMP.

2.5 Basic Introduction of EEDI

Because the original formula of EEDI is too cumbersome. Once the ship is completed, the EEDI of the actual ship can be calculated with the following shorten formula. The simplified calculation formula of EEDI is: EEDI = P * SFC * C / DWT * v. The P is 75% of the rated power, SFC is the specific fuel consumption, C is the oxidation conversion coefficient, which is generated by the specific fuel used, DWT represents the deadweight ton of the ship, and V is the ship speed under the design load.

As we all know that the types of ships, the sizes of the ships and the fuel used by the ships will have an impact on the ship EEDI. The implementation of EEDI has had a far-reaching impact on the shipbuilding industry, which will promote shipbuilding enterprises to continuously develop new materials and technologies, and promote the reduction of carbon emissions from newly built ships, so as to ensure that their products still have a place in the future competition.

2.6 Four Steps to Implement SEEMP

There are four steps to implement SEEMP, they are planning, implementation, monitoring, self-evaluation and improvement. The main measures in its implementation include: improving voyage plan, meteorological navigation, hull maintenance, etc.

The first step in implementing SEEMP is planning. The ship should first understand the current energy consumption of the ship, the energy-saving measures taken by the ship and the effect of these measures. The second step is to realize. The ship shall implement the time frame of SEEMP, the operators of each measure should be cleared and the records of the data should be reserved. The third step is monitoring. The ship shall collect the fuel consumed by specific machinery regularly and accurately, and a special person shall be responsible for the designated area. The fourth step is self-assessment and improvement. At this stage, the energy consumption should be compared with the previous consumption and the goals set in the planning stage. The self-evaluation stage should judge whether all energy efficiency measures is successful and provide meaningful feedback for future improvement in detail.

2.7 Measures to improve ship energy efficiency

Based on the existing researches, the author summarizes some effective measures to improve ship energy efficiency. The first is to reduce the loading of ballast water or develop non ballast ship types. While meeting the relevant requirements of ship ballast water, reducing the capacity of ballast tank and reducing equipped ballast water equipment can effectively reduce the total weight of the ship. At the same time, when the ballast tank capacity is reduced, the ship can use thinner steel, which also helps to reduce the total weight of the ship. Use new energy or alternative fuels, such as LNG, wind energy, solar energy and other new energy. Compared with traditional diesel fuel, these energy sources can effectively reduce GHG emissions such as CO_2 from ships. And these new energy reserves are large and its price is cheap. Today, with the depletion of traditional fossil fuels, it is particularly necessary to develop and utilize new energy. Replacing traditional steel with high-strength steel can effectively reduce the weight of the main structure of the ship and improve the energy efficiency of the ship. Because the character of high-strength steel is light weight and high strength. Optimizing the ship design and increasing the ship's cabin capacity can ensure that the ship can load as many goods as possible when transporting light goods. Optimizing the working conditions of the main engine, improving the combustion quality and appropriately reducing the speed can effectively improve the efficiency of the ship's main engine. Ships can be equipped with underwater energy-saving devices to reduce ship resistance, optimize wake and reduce power loss. At the same time, when painting the hull, pay attention to painting energy-saving coatings to prevent the attachment of seabed organisms and increase the ship resistance. When the ship is built, the streamlined superstructure can also reduce the ship resistance. Ships can adopt new propellers to improve the propulsion efficiency of ships.

To a certain extent, the two indicators of EEDI and SEEMP under MARPOL convention have effectively managed the whole process of ship operation from design and construction to operation management, which has greatly promoted the improvement of shipping energy efficiency and reduced shipping GHG emissions.

Table 2 IMO GHG Emission Reduction Approach

Table 4. IMO GHG emission reduction approach (GloMEEP 2018).

Approach	Type of Measure	Main Measures	Remarks
Technical approach	Improving energy efficiency	• Light materials • Slender design • Propulsion improvement devices • Less friction (air lubrication/hull surface) Waste heat recovery,…	EEDI framework
	Alternative/ New fuels	• Sustainable bio fuels • LNG • Hydrogen • Ammonia • Fuel cell • Electricity • Solar • Wind • Nuclear, …	
Operational approach	Improving operational practices	• Speed optimization • Ship size • Ship-port interface • Onshore power, …	SEEMP/EEOIa/ EEXIb
Market based approach		• ETS (Emission Trading Scheme) • EIS(Efficiency Incentive Scheme) • GHG Fund, …	MBM (Market Based Measures)

aEEDI: Energy Efficiency Operational Indicator
bEEXI: Energy Efficiency Existing Ship Index

Source: IMO's Research, (2021)

CHAPTER 3. SHIPPING SULFUR REDUCTION

AND SHIPPING NITROGEN REDUCTION

3.1 Hazards of Ships Using High Sulfur Fuel

Sulfur oxides refer to the sulfur dioxide, sulfur trioxide and other oxides of sulfur produced in the tail gas of ships after burning the sulfur-containing fuel. Most countries regard sulfur oxides as one of the indicators to judge air pollution. With the continuous development of shipping industry, the sulfur oxides in ship exhaust have become one of the main sources of sulfur oxides in the atmosphere. The research shows that the sulfur oxides emitted by ships will not only affect the coastal air quality, but also affect the inland air quality. Sulfur oxides in the air will irritate human respiratory tract, have an impact on human health, and also cause harmful weather such as acid rain. The United Nations and IMO have issued relevant policies to deal with the emission of sulfur oxides from ships. (Liu Yuning, 2020)

Figure 6 NOx and SOx Emission Trend in 2000-2030

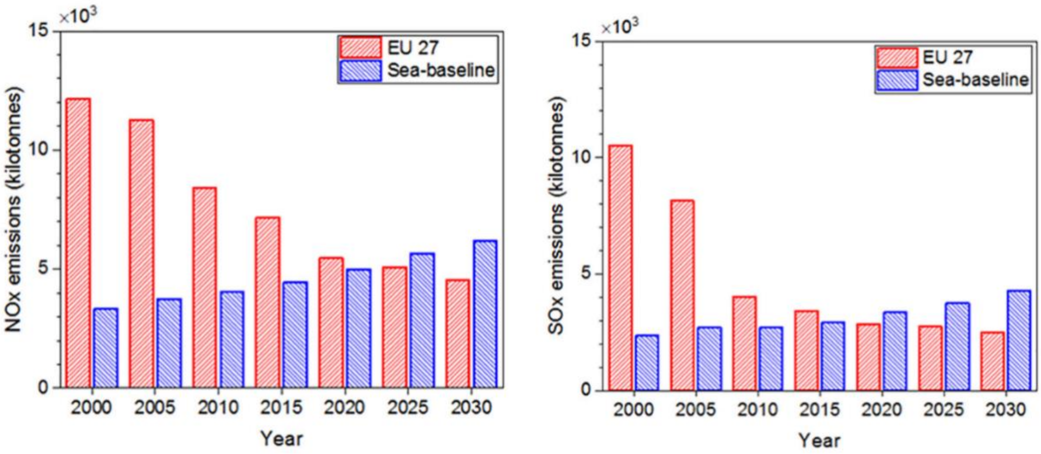


Fig. 1. NOx (a) and SOx (b) emissions trend in the 2000–2030 period (Salim Kamil and Saat, 2020).

Source: IMO's Research, (2021)

3.2 The Requirements of United Nations Convention on the Law of the Sea on the Emission of Sulfur Oxides from Ships

The United Nations adopted the United Nations Convention on the law of the sea (UNCLOS) in 1982, which entered into force in 1994. UNCLOS is a framework convention, which mainly stipulates issues such as maritime relations, maritime jurisdiction and marine environmental protection. In its Chapter XII "protection and preservation of the marine environment", UNCLOS reflects the relevant contents of shipping sulfur limitation, clearly stipulates the legislative power of marine environmental protection of various countries in the control of ship sulfur oxide emission, stipulates the jurisdiction of flag states, port states and coastal states in the control of ship sulfur oxide emission, and defines the general obligations of various countries in the protection of the marine environment (including the control of ship emission). UNCLOS, as a basic regulation of the oceans worldwide, has played a very important role in marine environmental protection and ship emission reduction. (Huang, Xia Yan, 2020)

3.3 IMO's Requirements on Shipping Sulfur Reduction

In 1999, the requirements for sulfur oxides in ship exhaust have been mentioned in Annex VI of MARPOL. At the same time, IMO also requires the manufacturer of marine diesel engine to ensure that its products meet the relevant requirements of the Convention and obtain the engine international air pollution prevention certificate. In order to improve the ship emission performance step by step, IMO demarcates four emission control areas (ECA) in the Baltic Sea, the North Sea, the Caribbean and North America, and first requires the improvements of ship emission level in these four ECA.

In 2008, IMO's MEPC revised Annex VI of MARPOL, requiring that the sulfur content of fuel used by global navigation ships should be reduced from 4.5% m / m to 3.5% m / m within six years from 2012. At present, the sulfur limitation task at this stage has been completed.

In 2018, IMO's MEPC adopted the latest amendment to Annex VI of MARPOL, namely MEPC resolution 305 (73), at its 73rd meeting. This resolution further improves the previous global sulfur limitation requirements. The resolution requires that from January 1, 2020, even ships sailing outside ECA need to use fuel with sulfur content less than 0.50% m / m, while within ECA, the sulfur content of fuel used by ships still needs to be less than 0.10% m / m.

In addition, MARPOL Annex VI also refers to alternative measures to reduce ship exhaust, such as the installation of exhaust gas washing system (desulfurization tower) and the transformation of ship fuel power system, using LNG or biofuel.

Figure 7 NOx and SOx Emission Trend in 2000-2030

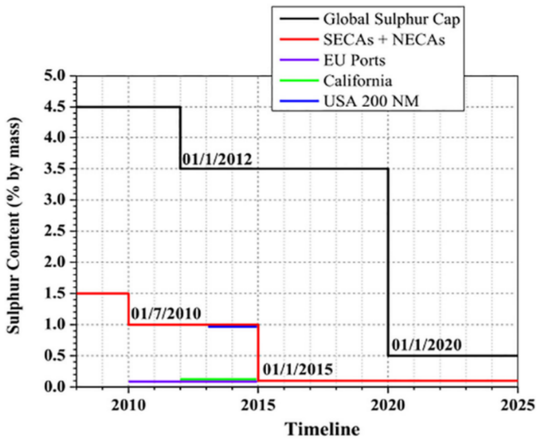


Fig. 3. Sulfur content change in fuel (Emission Standards, n.d.).

Source: IMO's Research, (2021)

3.4 Alternative Measures to Reduce Sulfur Content in Ship Tail Gas

3.4.1 Installation of scrubbers

In order to make the ship's tail gas meet the standard, in addition to using low sulfur fuel, the ship can also install tail gas cleaning system or use LNG fuel.

Considering the installation and transformation cost and the later operation cost, as well as the successful application of scrubbers in some roll-roll ships. Some dry bulk carriers and container ships are also considering installing scrubbers to meet the requirements of the Convention.

According to its working principle, scrubbers can be divided into dry desulfurization and wet desulfurization. According to its construction structure, it can be divided into single tower structure and double tower structure. When the dry desulfurization scrubber works, the ship tail gas enters the scrubber, moves and merges with the desulfurizer in the opposite direction. The desulfurization products are in dry state and no wastewater is discharged, which has little corrosion to the equipment. However, due to its slow reaction speed and other problems, wet desulfurization scrubber is mostly used in ships at present. The desulfurization scrubber with single tower structure is responsible for the desulfurization of all tail gas generated by boilers and generators on board. The desulfurization scrubber with double tower structure can distribute the desulfurized gas of the two towers as needed. In comparison, the cost of single tower scrubber is lower, and the use of double tower scrubber is more flexible. One tower can work alone or two towers can work together according to needs.

The principle of wet desulfurization scrubber is to use seawater or alkaline solution reagent to react with sulfur-containing tail gas to realize tail gas desulfurization. The desulfurization scrubber can be divided into open loop scrubbers, closed loop scrubbers and hybrid scrubbers according to whether the internal liquid is exchanged with seawater. Open loop scrubbers make use of the weak alkalinity of seawater to react with acidic sulfur-containing tail gas. For this kind of scrubbers, the installation and transformation are relatively simple, and the cost of alkaline reagent is saved at the same time. However, whether it directly discharges the reacted wastewater into the sea will have an adverse impact on the marine environment or not remains to be demonstrated. The closed loop scrubbers will react the fresh water added with desulfurization agent with the tail gas, and the seawater is only used as cooling water to cool the fresh water. The advantage is that the fresh water in the desulfurization scrubber circulates in a closed environment and will not affect the marine environment. However, due to the need to build equipment such as fresh water storage tank, circulation tank and dosing unit, it occupies a lot of space on board, and alkaline agents are also consumables. The construction and use cost of this kind of desulfurization scrubber is high. Hybrid scrubbers can switch between open working mode and closed working mode, with good adaptability.

However, since the covid-19 epidemic, some countries have relaxed the regulation of ship exhaust emissions, some countries even announced the suspension of sulfur restriction. The price gap between heavy oil and low sulfur fuel oil has been further narrowed due to changes in the international relations and the impact of supply and demand in the refined oil market. For these reasons, the attraction of installing scrubbers to ship owners is greatly reduced, and many ship owners shelve or postpone the installation plan of scrubbers.

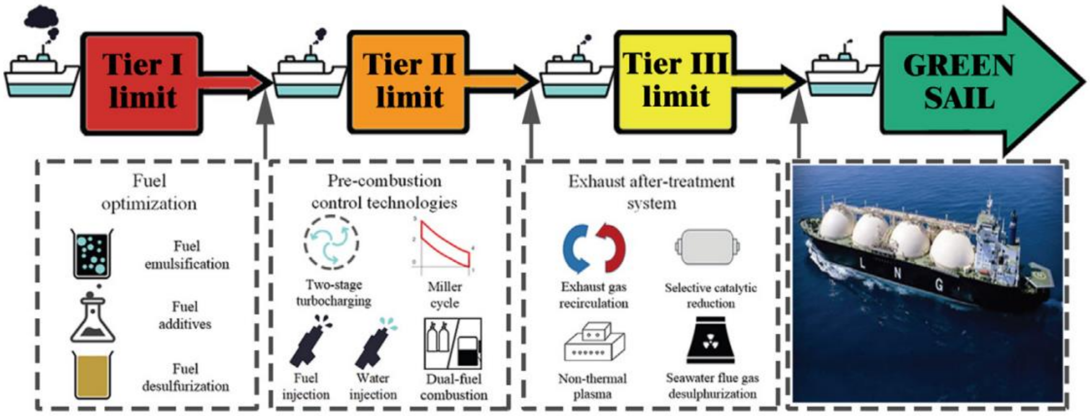
3.4.2 Using LNG fuel

The use of LNG fuel in ships is also an effective means to reduce sulfur oxides in ship tail gas. Compared with natural gas, LNG has smaller volume and is an ideal alternative fuel because of its sulfur-free, non-toxic and non-corrosive characteristics. However, there are some problems with LNG as ship fuel. The first is the consideration of cost. The price of engines that can use LNG as fuel is much higher than that of diesel engines. Compared with diesel oil, LNG has a larger volume and needs a larger storage compartment, which increases the shipbuilding cost to a certain extent. Second, from the perspective of policies and regulations, if a large number of ships transform the fuel from diesel oil to LNG, it is worth thinking about how to supervise and realize the coverage of regulations of the LNG ships. Moreover, some countries have regulations prohibiting the use of LNG in inland waters, which will also hinder the large-scale application of LNG by ships. The third is the availability of LNG. The charging facilities of LNG are needed by ships in the ports. And when the supply of LNG is tight, it is easy to affect the shipping industry. The fourth is the potential risk of promoting the use of LNG. The use of LNG in shipping can promote ship sulfur reduction. Because the main composition of LNG is CH_4, CH_4 will cause a greenhouse effect of 21 times than the same weight of CO_2 if it is leaked into the atmosphere under the condition of insufficient combustion. (Chu Haihong, 2021)

3.5 Shipping Nitrogen Reduction

As we all know that when a ship burns fuel to generate heat, it will also produce a certain amount of nitrogen oxides. Nitrogen oxides in the air not only damage human health, but also lead to bad ecological phenomena, such as acid rain and photochemical smog. IMO began research on reducing nitrogen oxides in ship exhaust as early as 1988. In 1997, MARPOL convention added Annex VI "rules for the prevention of air pollution caused by ships", which came into force in 2005. The Annex stipulates the NOx emission requirements of diesel engines with a power of more than 130kW on newly built or major refitted ships with keels from January 1, 2000. IMO requires that the nitrogen oxides emitted by these ship engines meets the three standards （tierI-III） according to the construction time. Tier I is applicable to ships built between January 1, 2000 and December 31, 2010. It requires that the emission of the marine engine reach the standard of 45.0 * n (- 0.2) g / kwh when the rotating speed is 130 to 2000rpm, and the emission of the marine engine reach the standard of 9.8g/kwh when the rotating speed is greater than 2000rpm. Tier II is applicable to ships built after January 1, 2011, which requires a 20% reduction in NOx emissions by Tier I. Tier III is applicable to ships built after January 1, 2016 and sailing in the emission control area, and it require a 80% NOx emission reduction by tier I. Tier I and Tier II are general provisions on the content of nitrogen oxides in ship tail gas, while tier III is a special provision for nitrogen oxides in ship tail gas discharged in emission control area (ECA). As more and more areas are designated as ECA, which means that more and more ships need to install engines that meet tier III emission requirements.

Figure 8 Three Tiers in the Reduction of the Nitrogen in Ships' Tail Gas



Source: IMO's Research, (2021)

3.5.1 Application of SCR System in Ships

Because IMO is implementing the Tier III standard of nitrogen reduction now, the current nitrogen reduction technology of marine diesel engine itself is difficult to meet the requirements of IMO. This requires diesel engine exhaust to meet the requirements of IMO through post-treatment technology. Among the post-treatment technologies, SCR is widely regarded as a mature and effective technology.

The full name of SCR is selective catalytic reduction. The principle is to add ammonia, urea or other nitrogen-containing compounds to the tail gas containing nitrogen oxides to turn NOx into N2 and H2O. The reduction reaction is carried out in a lower temperature range (315 ~ 400 ℃) and requires a catalyst, so it is called selective catalytic reduction.

The ship's SCR system is often composed of urea supply and injection device, catalyst device and electronic control unit. Because ammonia is toxic and there is a risk of leakage, urea is mostly used as reducing agent in ship SCR system. Before the reaction, urea and water are mixed with ship tail gas in a certain proportion. The urea solution is decomposed into ammonia and carbon dioxide due to high temperature, and ammonia reacts with ship tail gas. Catalytic device is the core of SCR system, which provides reaction place, reaction conditions and catalyst for NOx catalytic reduction reaction. There are four types of catalysts commonly used in SCR system, namely metal oxide catalyst, noble metal catalyst, molecular sieve catalyst and carbon-based catalyst. The operating cost of SCR equipment largely depends on the service life of the catalyst. Theoretically, the catalyst can be used indefinitely without participating in the chemical reaction. But in practical, many factors will lead to the deactivation of the catalyst. In order to prevent catalyst passivation from affecting the normal operation of SCR, replacing the catalyst regularly or trying to apply catalyst regeneration technology is very necessary. The electronic control unit is composed of urea liquid level sensor, temperature sensor and nitrogen oxide analyzer, which is used to monitor the operation status of each part of SCR system in real time.

The advantage of SCR system is that it can reduce the NOx emission of marine diesel engine without substantial modification by 80%-95% even when using poor quality fuel. Although SCR system has been widely promoted in the fields of thermal power and automobile, there is relatively little research on SCR system in the field of ship. In addition, SCR system occupies a large area and has a high cost, which also affects its wide use to a certain extent.

Figure 9 Different Nitrogen Emission in Different Speed

J. Deng, X. Wang, Z. Wei et al.

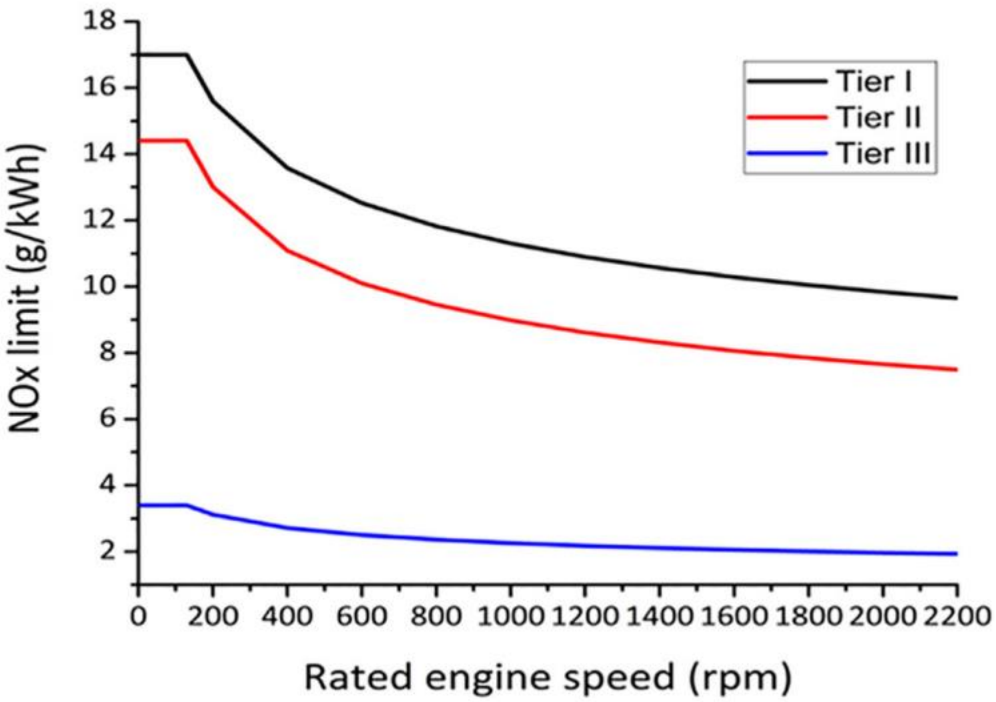


Fig. 2. MARPOL allowable limit for NOx emissions (Emission Standards, n.d.).

Source: IMO's Research, (2019)

CHAPTER 4. CHALLENGES FOR GREEN SHIPPING

The Green Shipping idea was established in 2004 with the purpose of reducing the environmental damage caused by marine transportation by measuring carbon emissions along shipping routes and employing alternative ships and facilities in operations. The primary goal of green shipping was to protect the maritime environment from fuel oil spills generated by ships. It is now widely adopted in many parts of the maritime sector, such as reducing ship pollution, regulating the use of clean fuels, and designing and building green ships. The international community and the shipping industry have put in significant effort to promote green shipping and have achieved significant progress in reducing ship exhaust emissions. By the end of 2021, ships with desulfurization towers account for 22.2% of the total number of ships in terms of worldwide shipping capacity, and LNG-fueled ships account for 21% of all new ship orders. Despite the volume of maritime transport climbed by 40.7% from 2008 to 2009, carbon emissions from shipping declined by 21.1%, accounting for 2.36% of global carbon emissions. Nevertheless, green shipping continues to confront numerous obstacles due to a variety of variables such as the COVID-19 outbreak, changes in international relations, and shipping market demand. (Zhu Wei, 2019)

4.1 Shortage of New Alternative Fuels

First and foremost, there is a lack of research into new alternative fuels. Currently, fossil fuels account for nearly all of the frequently utilized ship fuels, and it is far from sufficient to rely just on ship engine upgrades without changing ship fuel in order to meet the IMO 2050 emission reduction target. The shipping industry must create and implement a realistic system to minimize emissions, as well as develop and implement new alternative energy sources on a big scale, which will necessitate increased investment in alternative fuel research. There are still certain issues to be resolved in the commercialization of new alternative fuels, such as how to balance the safety, economy, and availability of hydrogen, solar, bio-cell, and wind energy to make the most scientific decision; whether existing carbon capture and storage methods are effective and if there are additional measures that can be implemented to promote carbon reduction; whether it promotes new alternative fuels and builds pollution reduction methods through active market regulation or requir ed government administrative procedures. These are difficulties that necessitate the collaboration of national maritime authorities, shipping customers, scientific research institutions, and upstream and downstream sectors, in addition to IMO's attention. (Zhen Lu & Zhuge Dan, 2020)

4.2 Mismatch between Traditional Policies and New Technologies

Secondly, when new environmental protection technology is applied in shipping, a condition occurs in which the previous shipping policy and regulatory structure cannot keep up. The existing international conventions on green shipping can be loosely classified into two categories. The first category consists of international treaties and standards with public law nature, such as MARPOL, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972, and so on. The other one is the international conventions with private law nature, such as the 1969 International Convention on Civil Liability for Oil Pollution Damage, the 1971 International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, and so on. Most of these early environmental conventions focused on topics like oil pollution damage, hazardous spills, and water pollution from cruise ships, and many of which were enacted in response to serious maritime safety and pollution disasters. The damage to the marine environment generated by exhaust gas during ship navigation, as well as the environmental pollution threats caused during ship building and disassembly, are typically overlooked in comparison to a large-scale maritime pollution event. The majority of present international environmental conventions concentrate on oil pollution and toxic products while give less attention to leakage with ship exhaust pollution, which has flaws and insufficiency. (Du Yuquan, 2012)

In terms of domestic environmental restrictions, the Chinese government has enacted a number of legislation and regulations aimed at promoting green shipping development, including the Air Pollution Prevention and Control Law of the People's Republic of China, the Domestic Emission Control Areas for Atmospheric Pollution from Vessels, and the 2020 global marine fuel limit sulfur implementation plan. (Lin Yu & Liu Changbing, 2020)These rules and regulations have established important requirements for reducing ship emissions and developing green shipping. Yet, they lack corresponding institutional regulation and adjustment in specific energy-saving and emission-reduction technologies, such as the use of low-sulfur oil, the installation of desulfurization towers, and the promotion of shore power use, and they do not clarify the legal responsibilities of newly emerged technologies in application. Although existing regulations have governed some new technologies, they are in desperate need of change due to bottlenecks in technology research and development, institutional impediments, and skewed legislative notions. (Huang, Liancheng& Zhang, Xianyong, 2021)

4.3 Operational Difficulties in the Development of Green Shipping

Thirdly, the current green shipping development path still poses some operational challenges. To begin with, unlike prior IMO regulations, the development process for the series of regulations on shipping emission reduction places an emphasis on setting an emission reduction target primarily, followed by promoting the development of relative environmental protection technology, that has resulted in the setting of emission reduction objectives that are too far ahead of the applicable provisions, which is difficult to implement in practice. The IMO, for instance, has made regulations on the sulfur content of fuel oil used in ships in MARPOL 1973 and other regulations. However, in the process of promoting low-sulfur fuel on a big scale, the relevant regulations frequently overlook safety risks of this product. Excessive wear and tear on the ship's oil dispensers, filters, and main engine sleeves has forced shipping giants Maersk and Duffy to pay an extra $2 billion and $1.5 billion each year to meet environmental requirements in promoting the widely use of low-sulfur fuel. (Yin, Hongxin, 2015)Vessels retrofitted with desulfurization towers face not only significant upfront costs, but also ongoing issues such as part maintenance and repair, greater vessel fuel consumption, and increased crew duty. LNG-fueled ships face challenges such as a lack of support infrastructure and high fuel prices. As evidenced by the aforementioned phenomenon, many regulations are presently created based on the achievement of a certain emission reduction objective and focus on the integrity of ship maneuvering technology, rather than take shipowner's actual running costs and operational issues into consideration. Upgrades to ship environmental protection systems frequently result in significant increases in operating expenses, which could have a significant impact on the survival of small and medium-sized shipping companies with limited financial resources. (Zhang Qiang & Chen Shun, 2022)

4.4 Green Barrier Caused by High Environmental Protection Standard

Fourthly, the shipping industry sets an unrealistically high standard for environmental protection, which can lead to a lack of market competition and the emergence of so-called “green barriers”. MARPOL Annex VI regulates on the ship energy saving and emission reduction stages, and the targets to be achieved at each stage according to the ship energy efficiency design index EEDI, ship type and deadweight tonnage. The global shipping industry has become increasingly consolidated in wealthier nations, intruding on the developing country shipping market and limiting investment for enterprises there as a result of the COVID-19 pandemic. Meanwhile, the pandemic outbreak lowered the rate at which new ships were delivered from shipyards, bringing challenges to emerging countries in updating in the massive number of large-age fleets. A “green shipping barriers” would objectively constitute if properly implemented in accordance with MARPOL Annex VI. These “green shipping barriers” does not happen instantly but were being gradually constructed as a result of the implementation of numerous international conventions, with only a few developed countries’ shipping industries being able to meet the standards. (Xing Hui, 2017) This barrier limits and compresses the development space of emerging countries’ shipping, and could result a profound impact on the global shipping pattern in the long run. Furthermore, the European Union has begun to collect carbon taxes on ships travelling to the EU territory without prejudice, which will have a severe influence on developing countries’ or small and medium-sized shipping businesses’ operations. Small and medium-sized shipping enterprises in developing countries have inadequate cash reserves, older and less well-off fleets, outdated environmental pr-tection equipment, and lower levels of ship operators when compared to advanced countries or large shipping corporations, and the carbon emissions per ship or per unit cargo tend to be higher than those of developed-country ships with modern technology. The ships of these developing countries or small and medium-sized shipping companies, will undoubtedly suffer a higher economic price in the face of the EU’s non-discriminatory carbon tax, with their competence and profit margin in the shipping market defined to be harmed further. The shipping market will become more concentrated in developed countries’ shipping firms or major shipping enterprises throughout the long term, intensifying the shipping imbalance. Simultaneously, the EU imposes a carbon tax on sea vessels based on carbon emissions, which runs counter to the UN’s principle of joint but differentiated responsibilities for developed and developing countries in the fight against climate change. (Yang Qiuping& Yan Jun, 2021)

4.5 Environmental Risk Caused by High Ship Charter during the Epidemic

Fifthly, High vessel rentals during the pandemic outbreak constitute an environmental concern. The number of anchoring pressures for bulk carriers, tankers, and container ships increased by 26.2%, 20.7%, and 32.1% respectively during 2020-2021, two years following the COVID-19 epidemic outbreak, as compared to 2018-2019, the pre-epidemic period. Tanker freight rates increased significantly in 2020, and VLCC freight rates set a new post-2008 high. In 2021, Bulk carrier charter rates reached a new high since 2008, owing to an increase in international cargo volumes and mounting pressure on ports. Container ship charter rates also hit an all-time peak. As a result of the epidemic, many ports now require ships to have been out of their last port for more than 14 days before approaching the port, resulting in a restriction in speed for all types of ships. The average speed of bulk carriers, tankers, and container ships was 11.33 knots, 11.05 knots, and 13.98 knots respectively in 2018-2019, down 0.8%, 0.5%, and 2.0% from the pre-epidemic period, implying that shipping companies need to invest more ships to meet the cargo needs on the same routes and with the same cargo volume. Due to the obvious high cost of ship chartering and the time needed for new ships delivery, shipping companies frequently risk the possibility of choosing ships that do not meet environmental protection regulations for maritime freight in the sake of profit. At the same time, due to quarantine and other factors, there is a short for international navigation crew and crew fitness has worsen. As a result, the crew is inclined to be physically incapable of to match the ship's maneuvering requirements, posing environmental dangers.

4.6 Other Factors Affecting Green Shipping

Aside from the factors above, the unbalanced international situation, the path to achieving the UN 2050 carbon reduction target, and the various prevention and control strategies of countries for the COVID-19 epidemic, as well as the allocation of carbon reduction shares between developed and developing countries, will all play a role in the implementation of green shipping. Hence, carbon reduction in the shipping industry should be evaluated thoroughly and executed in stages to accomplish comprehensive emission reduction without jeopardizing developing countries' interests.

CHAPTER 5. RECOMMENDATIONS FOR ACHIEVING

GREEN SHIPPING AND INSUFFICIENCY

At the moment, the shipping industry is confronted with numerous practical issues, including strict emission reduction standards, insufficient research on new alternative fuels, lagging requirements of international conventions related to environmental protection, countless practical issues in the development of green shipping, “green barriers” caused by the high environmental protection threshold in shipping, and environmental risks resulting from the COVID-19 epidemic. In light of the problems mentioned above, this paper attempts to make recommendations for improving and perfecting global shipping emission reduction metrics from the perspectives of legislation, emission reduction routes, technology, and policy implementation, in order to make future shipping emission reduction work more efficient and reasonable.

5.1 Prioritizing Research on New Alternative Fuels

To begin with, prioritize research in new energy alternatives for shipping. As a technical body for intergovernmental cooperation in the shipping industry, IMO should fully embrace its leadership position in determining the future course of the industry. It should encourage each contracting party to conduct independent research on alternative energy technologies, strengthen technical cooperation among governments, and motivate developing and underdeveloped countries to improve their own technological capabilities and achieve shipping emission reduction by participating in alternative energy research through technical cooperation and other means, all while remaining compliant with the existing legal framework. IMO can also work on the effectiveness of present carbon capture and storage methods in the annual carbon reduction studies undertaken under MEPC, and make tailored enhancements to current measures depending on the findings. In addition, IMO can collaborate with national maritime authorities, shipping companies, research institutions, as well as upstream and downstream businesses to develop and improve shipping emission reduction pathways and set up shipping emission reduction standards, giving rise in a cohesive effort to promote green shipping. Furthermore, IMO should expand research into the reliability and accessibility of new energy sources like hydrogen, solar, and wind energy, which are currently controversial in large-scale applications. (Xu Shanxiang, 2015)

5.2 Promoting the Amendments of International Conventions according to the Reality of Emission Reduction

The second way is to keep track of the timely amendment of international environmental protection conventions in light of the needs of emission reduction efforts. The MEPC stay up with recent research on maritime environmental protection and defined the findings that are widely recognized and put into action in the form of papers in international conventions. IMO should use international conventions as much as practicable to lead the industry in promoting the use of new fuels and define the legal duties of new technologies in use. Upon the basis of existing environmental protection conventions, IMO should improve relevant regulations on ship exhaust gas, and give certain policy inclination to countries and shipping enterprises that take the lead in promoting new energy technology, and allow those countries to contribute their experience to the development of industry standards for new energy in shipping. (Gao Yunqi, 2017)

5.3 Establishing an Emergency Mechanism for Marine Environmental Protection

under the Covid-19 Epidemic

Thirdly, an emergency plan should be established to ensure that environmental concerns at sea are not generated by similar extreme conditions in the case of a COVID-19 epidemic. IMO should take lessons from maritime monitoring during the COVID-19 epidemic and improve the environmental emergency plan. The rapid outbreak of the COVID-19 virus has had a detrimental impact on the international economy's development, and none of these countries and industries can be preserved well in difficult times; instead, they must take responses and rise to the challenge. IMO and national maritime authorities should closely examine possible non-compliant ships, personnel fitness circumstances, and the relative lack of oversight caused by rise in shipping rates during the pandemic, and acknowledge insufficient current system of environmental protection oversight of ships in special circumstances. The following three aspects can be employed to strengthen environmental protection oversight at sea in rare circumstances. The first one is to examine the existing regulatory system's management and coverage capabilities, as well as the flaws in daily regulatory activity. The second one is to make full use of new technological tools such as big data, 5G, and Internet plus. Remote environmental supervision employing contemporary technology can be advantageous in the event of unforeseen events and the failure of traditional techniques of supervision. Infrared remote sensing technology, for example, can be utilized in port regions to detect exhaust emissions from ships arriving in port. National maritime authorities can employ 5G communication networks to conduct remote PSC and FSC inspections of ships in order to gain a clear grasp of their anti-pollution activities. (Xu, F., Chen, G. Shuo, 2021)Ships will be able to communicate management information, real-time ship location, and other data with regulatory bodies in the future via blockchain technology. Thirdly, IMO and state maritime authorities should encourage shipping companies to fully employ their own self-regulatory mechanisms as each company knows the most about the state of its ships and the operational abilities of its crew, as well as the earliest identification of ship problems. We can assure maximum environmental safety at sea if we can fully utilize shipping companies' primary role in ship pollution prevention management through a sound ship integrity management mechanism. (Zhang Shouguo, 2020)

5.4 Ensuring the Fairness in Shipping Emission Reduction

Fourthly, assure equality in the reduction of shipping emissions and avoid the emergence of new sector barriers. IMO should play a pivotal role in the industry, actively involving developing countries in the formulation of international rules and standards relating to environmental protection, and enhancing the voice of developing countries in the international shipping industry in formulating new environmental protection policies. (Yang Lei, 2020)Simultaneously, the legislative idea that technology comes after regulation should be discouraged in the development of new environmental protection conventions, and the adventurous approaches taken in ship emission reduction should also be abandoned. Comprehensive surveys and studies should be conducted before a policy is formulated to ensure that the newly formulated policy will be accepted and executed by the large majority of countries, particularly emerging and undeveloped countries. IMO should try to play a more active role in the adjustment of carbon emission tax collection methods already in place in some countries and regions, such as suggesting that the EU takes the interests of developing countries more into account when adjusting carbon tax collection in order to ensure the necessary market competition. On the other hand, IMO can begin to develop a global emissions trading system for carbon dioxide, sulfur dioxide, nitrogen oxides, and particulate matter, while paying close attention to the principle of who benefits and who takes responsibility in order to ensure fairness.

5.5 Fully Adapt to the Changes in Shipping Market

Last but not least, encourage the adoption of international environmental protection conventions for shipping to actual emission reduction measures. IMO and other international organizations should conduct adequate research and formulate scientific emission reduction strategies and paths based on the realities of the shipping industry during the convention's formulation, in order to promote the switch to new fuels for ships at a reasonable pace. Maritime cargo markets are frequently affected by changes in ship fuel structures. Fossil fuels are currently the world's primary source of energy for shipping. By 2050, it will account for just over a 1/5 of overall energy supply, down from 4/5 today, signifying the undergoing transition of world's economy and sectors as well as the significant reorganization of global marine demand, trading patterns, and fleets. The market of certain ship types may contract, while the demand of new one will emerge. This imposes new obligations on the IMO, including the formulation of emission reduction programs and the selection of alternative fuels. When picking a new alternative energy source, ships must examine not just the its reliability, safety, and environmental performance, but also the storage capacity, market prospects, and price. These factors have to do with whether the alternative energy can be widely pushed by the shipping sector and thereby contribute to the growth of green shipping.

5.6 Insufficiency in the Paper

This paper compares the requirements for shipping exhaust emission reduction efforts, summarizes and reviews previous literature, displays current measurement standards and major assessments used by the shipping industry to limit carbon, sulfur, nitrogen, and other elements in ship exhaust, concludes the problems with current global shipping emission reduction efforts, and attempts to provide possible solutions.

Although this paper suggests certain improvements on present emission reduction efforts to the shipping industry, the majority of these are based on a evaluation and summary of previous literature and do not include field research, investigation, or quantitative model analysis. The proposals would be far more beneficial it there were a way to perform research and reasoning the topics presented in this paper.

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