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Study on current state and methods of marine carbon emissions MRV in Chinese shipping sector

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STUDY ON CURRENT STATE AND METHODS OF MARINE CARBON EMISSIONS MRV IN CHINESE SHIPPING SECTOR

By

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The People's Republic of China

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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.

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Date: June 27, 2019

Supervised by:
Sun Deping
Professor of Dalian Maritime University

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ABSTRACT

Title of Dissertation: **Study on current state and methods of marine carbon emissions MRV in Chinese shipping sector**

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Although the shipping industry is one of the most energy efficient modes of transportation, the carbon emissions per unit cargo are still in a high position. Under the current international, domestic and shipping background, shipping enterprises are not only facing fierce competition in the industry, but also meeting the constraints and requirements of relevant international mandatory conventions and regulations. IMO and EU have adopted some feasible measures for ship carbon emissions, such as ship energy efficiency management plan, ship carbon emission monitoring methods, etc., to gradually control ship carbon emissions and improve the efficiency of ship energy saving and emission reduction.

For the shipping industry, the active participation of shipping companies in carbon emission MRV (monitoring, reporting and verification) can truly and accurately reflect the status of carbon emissions in the shipping industry, which can make the research direction of energy saving and emission reduction more accurate. At present, China's domestic shipping companies with the European market as the main business target can report carbon emissions data according to the requirements of the European Union. However, the accuracy of the data is still insufficient. Some relevant organizations and countries at home and abroad have also made efforts to study the methodology of MRV work, providing strong technical support for more accurate and efficient MRV work on ship carbon emissions.

KEY WORDS: MRV（monitoring, reporting, verification）, GHG, emissions reduction, inventory, China, shipping sector

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LIST OF ABBREVIATIONS

CCER	Chinese Certified Emission Reduction
DWT	Deadweight Tonnage
EU	European Union
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
EPA	Environmental Protection Agency
DWT	Deadweight Tonnage
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
GHG	Green House Gas
GDP	Gross Domestic Product
GHGRP	Greenhouse Gas Reporting Program
IPCC	Intergovernmental Panel on Climate Change
IMO	International Maritime Organization
IFO	Intermediate Fuel Oil
IMO	International Maritime Organization
MRV	Monitoring、Reporting and Verification
MEPC	Maritime Environment Protection Committee
MGO	Marine Gas Oil
MDO	Marine Diesel Oil
MBM	Market-Base Measure
MARPOL	The International Convention for the Prevention of Pollution From Ships

SEEMP	Ship Energy Efficiency Management Plan
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WTO	World Trade Organization

CHAPTER 1

INTRODUCTION

1.1 Background information about MRV

From the international background, greenhouse gas (GHG) has become the focus of international attention. Global climate change caused by excessive greenhouse gas emissions is the most important environmental problem facing mankind at present. According to data released by the World Bank[1], trends in global carbon emissions from 2010 to 2014 are shown in Figure 1.1.

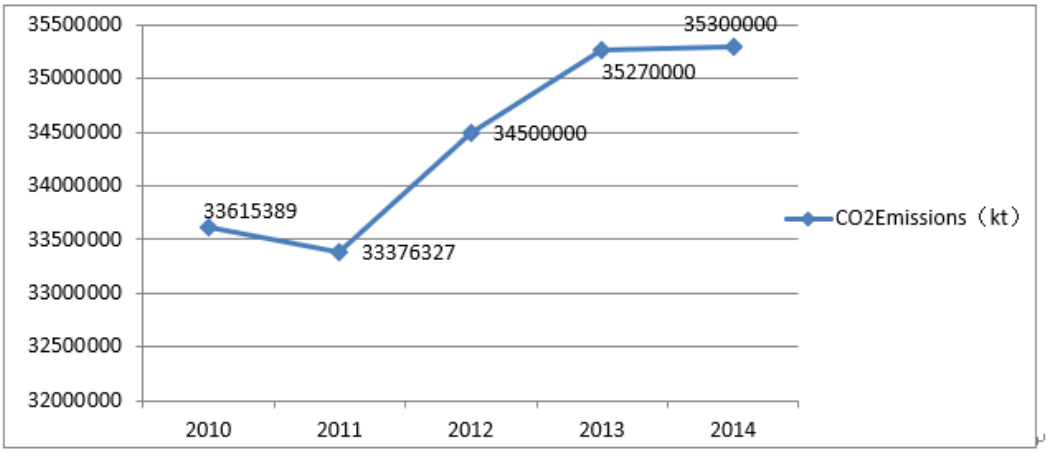


Figure 1.1: Global carbon dioxide emissions

Source: https://data.worldbank.org/indicator/EN.ATM.CO2E.KT

As early as thirty or forty years ago, major countries around the world began to pay more attention to the changes of the earth's environment. Among them, greenhouse

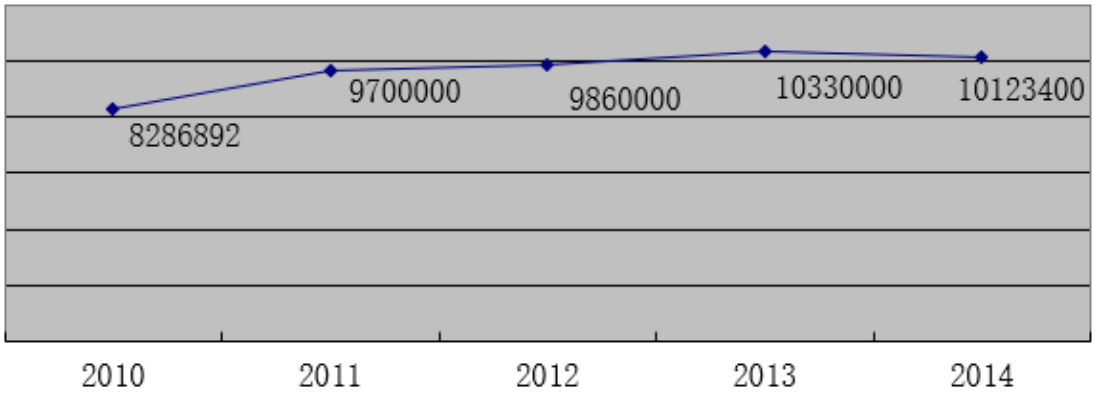
[1] http://data.worldbank.org/indicator/EN.ATM.CO2E.KT/countries.

gases have a significant impact on the ecological environment of the whole earth. In recent years, under the influence of global environmental trends, the international community has invested a lot of work in energy conservation and emission reduction, not only from the source of energy consumption control, but also to take various measures to reduce greenhouse gas emissions, especially carbon dioxide emissions. Globally, many world organizations have made tremendous efforts on the earth's ecological environment. Among them, the Intergovernmental Panel on Climate Change (IPCC), which was jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988, is more famous. The organization is trying to promote research and time in the field of carbon emissions from both scientific and political perspectives, so that international governments can exchange and cooperate with each other to achieve the goal of reducing world carbon emissions. In order to control the emission of greenhouse gases such as carbon dioxide and to mitigate and avoid the adverse effects of global climate change on the economies and societies of countries, the Committee reached the same opinion on global climate change in 1992 and launched a programmatic document, the United Nations Framework Convention on Climate Change (UNFCCC).) A few years later, in 1997, at the third meeting of the Parties to the Convention, the Kyoto Protocol, the well-known Kyoto Protocol to the United Nations Framework Convention on Climate Change, was formulated, which we often hear about. The Kyoto Protocol provides legal constraints on quantitative emission reduction and emission limitation indicators in developed countries. In 2007, the Bali Action Plan was formulated to address the problem of no legal document binding member States after the end of the commitment period of the Kyoto Protocol. Its Article 1 (b) (ii) stipulates that "In order to ensure the effectiveness of developing countries emission reduction obligations, developed countries require such actions to be measurable, reportable and auditable'; correspondingly, developing countries also require developed countries to fulfil their long-standing obligations to provide technology transfer and financial support that they have not been able to effectively

fulfil, and such obligations should also be measurable, reportable and auditable'. "At the end of 2009, the fifteenth Meeting of States Parties was held in Copenhagen, Denmark. Developed countries and developing countries formally formed two camps, and finally reached a non-legally binding Copenhagen Accord. In the scientific aspect, IPCC's research mainly focuses on proposing and constructing the paradigm and framework of carbon emissions accounting; publishing the Research Report on global climate change; publishing the guiding list of greenhouse gas emission sources, and supplementing the calculation methods separately.

For some traditional industries with huge energy consumption, such as power plants, metal smelting and engineering construction, it has also become the focus of carbon dioxide emission audits in developed countries and some international organizations. At the same time, scientific research institutions and researchers around the world have also carried out in-depth research on the carbon emissions of their countries, the main direction is to develop more targeted carbon emissions inventory; More effective calculation methods and formulas are constructed. And from the large level to the small level, from the organization to individual levels and scales to carry out practical work.

In China, according to the "Trends in Global CO2 Emissions: 2014 Report[2] published by the European Commission and Netherlands Environmental Assessment Agency, China's carbon emissions in the past few years are shown in Figure 1.2.



[2] http://www.pbl.nl/en/publications/trends-in-global-co2-emissions-2014-report.

Figure 1.2: Total Carbon Emissions in China in Recent Years

Source: http://www.pbl.nl/en/publications/trends-in-global-co2-emissions-2014-report

As can be seen from Figure 1.2, China's CO2 emissions have been at a high level. The government attaches great importance to climate change. It regards tackling climate change as a major strategy for economic and social development, puts forward the development concept of "energy saving, emission reduction, green environmental protection", and determines the action objectives of actively responding to climate change: By 2020, on the basis of 2005, carbon dioxide per unit GDP will be reduced by 40% to 45%, non-fossil energy will account for 15% of primary energy, and forest carbon sinks will be increased. Transportation industry, as a key industry of carbon emissions, also pays more attention to energy conservation and emission reduction. In July 2011, the Ministry of Transport issued the 12th Five-Year Plan for Energy Conservation and Emission Reduction of Highway and Waterway Transportation, which clearly put forward the indicators of energy intensity and CO2 emission intensity during the 12th Five-Year Plan period. The energy intensity index is "compared with 2005, the energy consumption per unit transport turnover of operating ships has decreased by 15%, of which marine and inland ships have decreased by 16% and 14%, respectively." The CO2 emission intensity index is "compared with 2005, the CO2 emission per unit transport turnover of operating ships has decreased by 16%, of which marine and inland ships have decreased by 17% and 15%, respectively." At the same time, the construction of 10 key projects has been proposed. “Green Port and Navigation Construction Project, Ship Energy Efficiency Management System and Database Construction Project and Energy Saving and Emission Reduction Supervision Capacity Building Project. It can be seen that earnestly doing a good job of MRV carbon emissions and reducing the carbon emissions of shipping enterprises have become one of the key tasks of the national transportation industry.

At the same time, China has made carbon trading pilot project as a key work to control greenhouse gas emissions during the 12th Five-Year Plan period. Some

commentators pointed out that as of May 2015, China's high-expectation carbon trading market had been running for two years. Despite more and more attention at home and abroad, the market has not yet brought the participants a definite direction. Problems such as excess quota allocation, downward economic impact, CCER control and unclear rules of the national carbon trading market are plagued by players who have struggled in the market and want to enter the market. Among the many factors affecting the healthy development of China's carbon trading market, MRV system is the lifeblood of carbon trading. In other words, whether a fair, effective and conservative MRV system can be established is the key to the success or failure of China's carbon market. At present, some provinces, such as Beijing, Shanghai, Guangdong and Hubei, have established regional carbon emissions trading system based on their own reality. At the same time, some industries have established carbon emissions monitoring, reporting and auditing system. On October 15, 2013, the National Development and Reform Commission issued power generation, power grid, steel, chemical industry, electrolytic aluminum, magnesium smelting, flat glass, cement, ceramics, civil aviation, etc (Zhou,2019). In December 2014, the second batch of accounting methods and reporting guidelines for greenhouse gas emissions from four industries, including China Petroleum and Natural Gas Enterprises, Petrochemical Enterprises, Independent Coking Enterprises and Coal Production Enterprises, was issued. It can be said that the establishment of carbon emission audit methods and reporting guidelines for China's shipping enterprises is the general trend. (Zhang,2015)

For the shipping industry, although we can learn from the technology and methods of carbon emission MRV in some parts of China and related industries, and also refer to the relevant international regulations on carbon emission MRV, China's shipping industry has its own particularities, mainly reflected in the following aspects:

1. Data accuracy is not high. Compared with other domestic industries, MRV data of

carbon emissions from ships are difficult to obtain accurately. This is because ships have considerable flexibility in the process of operation, and it is difficult to collect emission data, set baselines and monitor emissions. As a result, China's shipping industry's carbon emission reduction preparation has been weaker than the aviation industry. For a long time, waterborne enterprises have been making continuous efforts in the measurement of "fuel consumption", trying to "find out the bottom of the house" as far as possible and accurately grasping the data of ship fuel consumption, but so far there is no effective method. The uncertainties of ship fuel quantity are mainly caused by inaccurate refueling quantity, inaccurate monitoring of unit fuel consumption, inaccurate measurement of residual oil storage and inaccurate human factors.

2. Few references object. The recommended methods of IMO and IPCC are limited to the calculation of carbon emissions, and the reference of MRV technology is not strong. At present, there are few countries and regions that carry out carbon emission MRV work in the maritime industry. The EU formally introduced the draft regulation of carbon emissions in the maritime field as early as June 28, 2013. However, it was not until May 19, 2015 that the regulation method was formally announced, requiring ships with more than 5,000 gross tones docked in EU ports to make mandatory annual reports on carbon dioxide emissions regardless of their registry. However, there are still many regulations in this regulation method. Many uncertain, inaccurate and non-operable problems need to be solved, and they are limited to the monitoring of CO2. Although in some aspects, they have reference value for China's carbon emission MRV, but they are not strong. However, other countries and regions have not yet carried out the relevant provisions on MRV of ship carbon emissions.
3. Regulators have strong liquidity. Shipping industry itself is a global activity. Because of the unstable routes, ships on international routes may sail abroad every year without calling on domestic ports. Refueling and other operations occur abroad, which brings great difficulties to MRV work of ship carbon emissions.

1.2 Objectives of research

1. Audit objects. The purpose of the accounting methods and reporting guidelines for greenhouse gas emissions in key industries compiled by the National Development and Reform Commission is to help enterprises to scientifically calculate and standardize their own greenhouse gas emissions, formulate greenhouse gas emission control plans for enterprises, actively participate in carbon emissions trading, strengthen corporate social responsibility, and establish and implement greenhouse gas reporting for key enterprises for competent departments. In order to lay the foundation for the system, does MRV audit of carbon emissions need to be carried out for the convenience of flag ships and a considerable number of ships in waterborne enterprises are international ships? Does a considerable number of foreign ships berthing in our ports need MRV audits for their carbon emissions?
2. Audit calculation method. Due to the imperfection of the relevant calculation methods and the difference between IMO and IPCC, how to determine the calculation method of carbon emissions in water transport enterprises is the focus and difficulty of this work.
3. Data acquisition. Due to the inaccuracy of ship data acquisition, how to accurately acquire ship energy consumption related data and determine the uncertainty is the difficulty of this work.
4. The scope of the report. Like other industries, the scope of the MRV report for carbon emissions from shipping enterprises needs to be determined.

CHAPTER 2

The current status of ship carbon emissions in China and other country

2.1 Current status of International shipping

The growing global greenhouse effect has been related to the future development of human destiny, and not only the problem of human living environment, but also a political issue among countries. In the global carbon emissions of all industries, although the carbon emissions generated by ships only account for a small part of all global carbon emissions, the International Maritime Organization (IMO) has studied and predicted that if the corresponding energy-saving and emission reduction measures for ships are not taken, the carbon emissions generated by ships will account for nearly 20% in the coming decades. In view of the increasingly urgent situation, the amount of carbon emissions of China's water transport enterprises has not been published in detail. Fully understanding the actual situation of carbon emissions of domestic water transport enterprises can help the state and enterprises to establish effective carbon emission detection methods and formulate effective reporting and auditing systems.

In view of the high carbon dioxide emissions of the world's shipping industry, the International Maritime Organization issued Third IMO GHG Study 2014 in 2015. The report publishes global marine greenhouse gas emissions (mainly carbon dioxide) between 2007 and 2012. According to relevant statistical data, the total amount of carbon dioxide emitted by ships in the world in 2012 was about 796 million tons, which was reduced by 899 million tons compared with 885 million tons in 2007. At the same time, the ratio of ship emissions to global emissions in 2012 was also lower

than in 2007.The specific data are shown in Table 2.1.

Table 2.1: Global Carbon Dioxide Emissions from Maritime Industry (2007-2012)

Year	Global CO2 emissions	Emissions from all ships	Total as a% of world total	International Ship Emissions	Total as a% of world total
2007	31409	1100	3.5%	885	2.8%
2008	32204	1135	3.5%	921	2.9%
2009	32047	978	3.1%	855	2.7%
2010	33612	915	2.7%	771	2.3%
2011	34723	1022	2.9%	850	2.4%
2012	35640	949	2.7%	796	2.2%
Average	33273	1016	3.1%	846	2.6%

Source: http://www.green4sea.com/wp-content/uploads/2015/05/Third-IMO-GHG-Study-Full-Report-5_2015.pdf

According to the research of Third IMO GHG Study, it is predicted that between 2012 and 2050 the growth rate of carbon dioxide emissions will reach 50% to 250% by 2050 if effective energy-saving and emission reduction measures are not taken to reduce the carbon emissions of the marine industry. Secondly, the expected results of new energy and clean energy in the future are not ideal, so fossil fuels will still be the main energy fuels used by ships. And other greenhouse gases will increase over time, except for carbon dioxide, but NOX and SOX will not increase significantly and are expected to remain at a lower level.

The world shipping market is closely related to the changes of the world economic situation, and the prosperity of the industry will be impacted by all walks of life. The total amount of carbon emissions is directly related to the prosperity of the industry. However, in view of the current situation of energy saving and emission reduction in the world, the prospects for low carbon and environmental protection of ships are still very optimistic. Many countries around the world are constantly strengthening control efforts and actively developing new energy-saving and emission reduction technologies, so we also believe that in the future, the carbon emissions of ships will

gradually show a downward trend.

2.2 Current status of China

In terms of emission data, the data of carbon emissions from water transport are published in the whole transportation industry. In 2011, the National Development and Reform Commission, the Office of the National Energy Leading Group and the National Bureau of Statistics established the communique system of GDP energy consumption indicators. At the end of June, the National Bureau of Statistics publishes to the whole society the energy consumption of 10,000 yuan of GDP and the reduction rate and scale of energy consumption of 10,000 yuan of GDP in the previous year. The above industrial enterprises have 10,000-yuan industrial added value energy consumption and 10,000-yuan GDP electricity consumption index, but lack of relevant data in the actual query. The Twelfth Five-Year Development Plan of Transportation clearly states that the water transport industry carries out energy saving and emission reduction activities. Compared with the Eleventh Five-Year Plan, the energy consumption and carbon dioxide emissions per unit of transport turnover of operating ships decrease by 15% and 16%, respectively. According to the data released by the Ministry of Transport, in 2012, China saved 1.28 million tons of standard coal, reduced 2.88 million tons of CO2 emissions, and reduced 2.3% of the energy consumption per unit transport turnover of operating ships; in 2013, China saved 1.34 million tons of standard coal by waterway transportation, reduced 3.03 million tons of CO2 emissions, and reduced 2.3% of the energy consumption per unit transport turnover of operating ships.(Song, 2014)

At present, according to the requirements of relevant international organizations and our government, China's shipping enterprises have made great efforts to take measures to save energy and reduce emissions as far as possible. These measures mainly include traditional measures, such as optimizing the speed of ship’s routes, reasonably operating ships, strengthening the management and maintenance of ships, paying attention to the management of ships and engines, and carrying out special

activities of energy conservation on ships. New technological measures are also being applied in ship operation, such as improving ship type, using clean energy including shore points, renewing and innovating emission reduction equipment, establishing exhaust gas circulation system, air lubrication system, and cooperating with relevant research institutes to innovate technology and improve related equipment.\

However, there are some contradictions in China's shipping enterprises as a whole. These contradictions are mainly concentrated in the following aspects: first, the contradiction between enterprise profits and investment in emission reduction equipment, the current situation of shipping downturn, many shipping enterprises operating at a loss, often do not have the capital capacity to carry out equipment transformation to achieve emission reduction goals; The second is the contradiction between fuel quality and price. The fuel consumed by ships must emit CO2. The quality of fuel fundamentally determines the amount of carbon emissions from ships. Shipping enterprises generally take into account when choosing refueling, and choose low-quality and low-price fuel to reduce costs. Third, the contradiction between fuel saving and freight. In the case of low shipping market, low transportation pressure and high oil price, shipping enterprises reduce the speed of ship operation and main engine speed in order to reduce fuel cost, which also effectively reduces the carbon emissions of ships. However, when the shipping market warms up slightly, the pressure of ship transportation increases, the oil price is low, and the ship rent is high, enterprises tend to do so. No longer focus on fuel economy, but more on freight; Fourthly, the contradiction between profit and heavy pollution of old ships. After a certain number of years of operation, the ship's various conditions are relatively stable, the required equipment input is reduced, and the maintenance cost is reduced. This is the time when the profit of the ship is maximized. But at this time, because of the backward equipment and the old ship, it is also the time when the CO2 emissions are the largest.

2.3 Investigation of the situation of ship carbon emission in China

2.3.1 COSCO Container Transportation Co., Ltd

Before the reorganization and integration of COSCO Group and China Shipping Group. COSCO Container Transport Co., Ltd. is the core enterprise of COSCO Group which specializes in maritime container transport. The company owns 149 ships in 2009, 146 ships in 2010, 146 ships in 2011, 174 ships in 2012 and 185 ships from 2013 to December. In terms of ship type, it can be divided into 88 super Panamax ships, 25 Panamax ships, 4 sub Panamax ships, 30 handy ships and 35 others according to ship size. In terms of routes, 162 ports in more than 49 countries and regions are connected globally. They operate 84 international routes, 23 international feeder routes, 23 coastal routes of China and 79 feeder routes of the Pearl River Delta and Yangtze River. The annual container volume reaches 80,16241 standard boxes. The volume of domestic trade ships is relatively small, mainly in domestic navigation, with 10 main domestic trade routes; The volume of foreign trade ships is large. The routes mainly include trans-Pacific routes, Far East/European Mediterranean routes, South/North and other international routes.

The main types of fuel used by container ships are: Marine gas oil (MGO), Marine diesel oil (MDO), Intermediate fuel oil (IFO) and Heavy fuel oil (HFO). For some areas requiring the use of low-sulfur fuel oil in Europe and the United States, the required fuel oil is used according to local regulations, and all the fuel oil consumed by ships (light oil, heavy oil) and lubricants are purchased. The energy consumption and energy consumption index of COSCO in recent years are shown in Table 2.2.

Table 2.2: COSCO Container Transportation Co., Ltd. Energy Consumption and Index (2009-2013)

Year	Number of ships	Oil consumption (tons)			Unit oil consumption(kilogram/kiloton/mile)		
		MDO	HFO	Lubricant oil	MDO	HFO	Lubricant oil
2009	149	62890.66	2298810.63	18023.26	0.22	8.07	0.06
2010	146	71271.47	2349517.84	18747.07	0.21	6.98	0.06
2011	144	68472.82	2589986.92	18217.60	0.19	7.03	0.04
2012	174	69657.2	2741783.5	17188.85	0.16	6.48	0.04
2013	185	82530	2537470.0	15800.0	0.19	5.85	0.04

2.3.2 EU Standard Data Analysis

According to the latest requirements of Annex II-B of the European Union's CO2 monitoring method[3], the four data required are as follows:

1. Fuel consumption per distance = total annual fuel consumption/total distance travelled;
2. Fuel consumption per transport work = total annual fuel consumption/total transport work;
3. CO_2 emissions per distance = total annual CO_2 emissions/total distance travelled;
4. CO_2 emissions per transport work = total annual CO_2 emissions/total transport work.

Based on the recognized basic ship types in the current shipping market are bulk cargo, container and liquid cargo ships, we have tracked two representative bulk cargo (B1, B2), two containers (C1, C2) and four oil tankers (T1, T2, T3, T4). Since the EU regulated ship carbon emissions take voyage as the cycle, we have tracked the voyage data of the above eight ships for the whole year of 2014. Ship data and data analysis can be found in the Table 2.3 and Figure 2.1 and Figure 2.2

[3] REGULATION (EU) 2015/757 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

Table 2.3: Basic information of ships

Sequence number	Ship Code	Ship type	Length*Breadth (meter)	Size of the ship	Annual voyage	Route
1	B1	Bulk	292*45	Suezmax	5	Global
2	B2	Bulk	225*33	Panamax	7	Global
3	C1	Container	188*28	Handysize	17	Global
4	C2	Container	243*32	Panamax	23	Global
5	T1	Oil	229*32	Panamax	18	Global
6	T2	Oil	275*48	Suezmax	9	Global
7	T3	Oil	245*42	Aframax	14	Global
8	T4	Oil	330*60	VLCC	5	Global

The above ships are all globally sailing ships, and their types and sizes are very representative. Their navigation data can reflect the current situation of energy consumption of ships operated by China's shipping enterprises.

Figure 2.1: Ship fuel consumption data (tonnage per nautical mile)

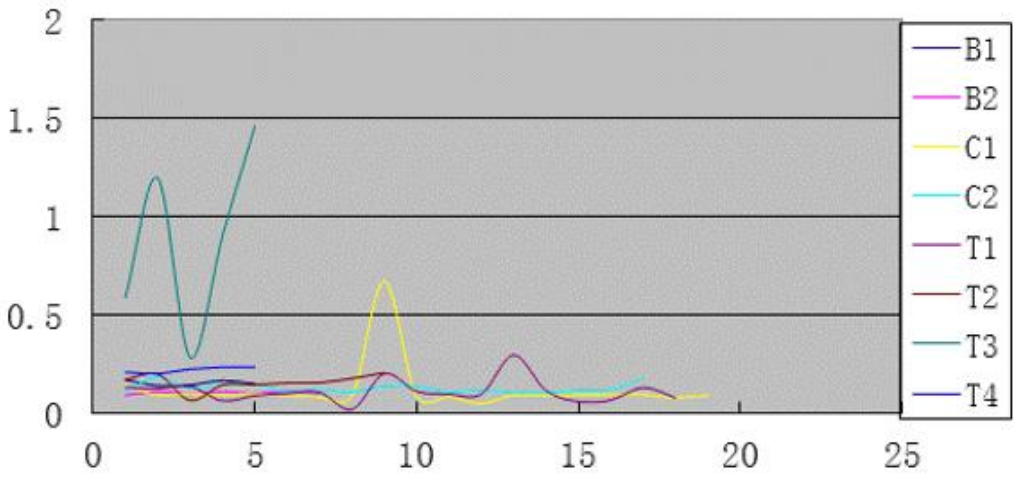
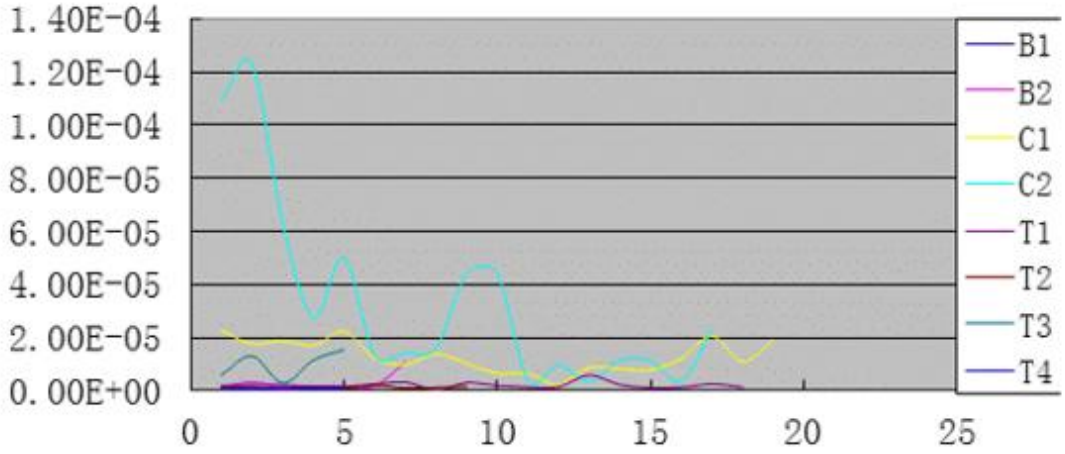


Figure 2.2: Data of Heavy Oil Consumption per Cargo Turnover (tonnage per nautical mile)



In data processing, since the whole voyage of a ship is not all cargo carried in the whole voyage, the relevant data of the ship's cargo voyage are calculated by referring to the general calculation method of cargo turnover in our country, and the relevant data of the ship's ballast state are not calculated. The two statistics of CO2 emissions per mile and weekly turnover CO2 emissions are no longer calculated because they are calculated by fuel and CO2 conversion coefficient (CF) based on the data in Figure 2.1 and Figure 2.2. According to the relevant data in the above table, we can find the following points:

1. Each data line is basically stable, and its height indicates the data level of the ship in the relevant indicators.
2. The large fluctuation of single vessel data is due to the existence of multiple loading or unloading ports, or the refueling and lock-crossing activities of the vessel in the process of loading, so the calculated data have a large fluctuation.
3. There is a phenomenon of high fuel consumption per unit distance in oil tankers.
4. Container ships consume more energy per unit turnover. Due to insufficient cargo supply, there are many ports with low cargo and frequent loading and unloading. Therefore, it is difficult to improve the economic benefits of unit fuel.

CHAPTER 3

The current status of ship carbon emissions MRV of shipping company

3.1 Situation of MRV management of shipping company from national level

In China, the leading bodies for energy conservation and emission reduction in various industries are the State Council Leading Group on Energy Conservation and Emission Reduction and the National Leading Group on Climate Change Response. The main executive departments are the Department of Resources Conservation and Environmental Protection of the National Development and Reform Commission, the Department of Climate Change Response and the Department of Economic Construction of the Ministry of Finance. The Ministry of Transport has set up a special office for energy conservation, emission reduction and climate change response. In 2011, the Ministry of Transport issued the 12th Five-Year Plan for Energy Conservation and Emission Reduction of Highway and Waterway Transport, which puts forward strict specific requirements for energy conservation and emission reduction of waterway enterprises and ships. At present, there is no systematic development of MRV for marine enterprises. How to accurately obtain the fuel and carbon emissions of ships and determine the uncertainty of fuel quantity are the key and difficult points of monitoring. The report can draw lessons from the existing systems and methods. Auditing work similar to other industries is the shortboard of MRV work.

Carbon emission monitoring and reporting in water transport enterprises. At present, there is still a big gap between the unit energy consumption of transportation industry in China and that of advanced countries. Transportation industry is a key

energy-saving and emission-reducing industry determined by the State Council. The energy consumption of transportation industry accounts for about 8% of the total energy consumption of society. The Ministry of Transportation has formulated a series of systems, adopted a series of measures and carried out a series of activities to promote energy-saving and emission-reduction of transportation industry. Among them, the most representative and main action in the work of ship carbon emission audit and report is "Special Action for Low Carbon Transportation of 1000 Enterprises of Vehicles, Ships, Roads and Ports", which covers China's COSCO, China Sea and other major shipping enterprises. Participating enterprises are required to improve energy saving and emission reduction measures during the "Twelfth Five-Year Plan" period, and report relevant data every six months. See Appendix 1 for details.

The 12th Five-Year Plan of Transportation proposes the establishment of statistics and assessment mechanism for energy conservation and environmental protection of transportation. In terms of greenhouse gas emission reduction, it proposes the establishment of basic statistics and accounting system for greenhouse gas emissions at the national, local and enterprise levels, the adoption of target responsibility system, and the monitoring system for reporting greenhouse gas emission data directly by key enterprises.

In the aspect of carbon emission audit of shipping enterprises. In accordance with the practice of international maritime industry, the Ministry of Transport adopted the third-party auditing method similar to the carbon emission auditing work carried out by other provinces and municipalities. In November 2012, the Ministry of Transport promulgated the Interim Measures for the Recognition of Third-Party Auditing Institutions for Energy Conservation and Emission Reduction in Transport, which stipulated in detail the qualification, responsibilities and supervision of the third-party In January 2013, the first batch of 23 auditing bodies were announced, including 5

auditing bodies specializing in waterways, including China Classification Society Quality Certification Corporation.

From the above management status, we can see that the monitoring and reporting system of carbon emissions of water transport enterprises mainly relies on the enterprises themselves to determine energy consumption and report in accordance with the prescribed format. There are obvious deficiencies in the strength and comprehensiveness of supervision, as well as in the reliability and reliability of data acquisition. In the third-party auditing, the number of auditing bodies is small, the auditing ability is not uniform, the auditors are not professional, the auditing system is not mature and sound, and the lack of standards and norms for carbon emission certification and accreditation, these shortcomings are relatively consistent views in the shipping industry at present. Next, in view of the carbon emission auditing work of the shipping enterprises, we should improve the third-party carbon emission certification auditing system of the shipping enterprises as soon as possible, strictly enforce the access threshold of the third-party auditing bodies, cultivate a number of third-party carbon emission auditing bodies, standardize the work flow of carbon emission certification and verification, strengthen the management of the third-party organizations, and formulate guidelines for carbon emission monitoring and accounting of the shipping enterprises. Real enterprise carbon emission monitoring accounting basis. Comparisons between EU and China's greenhouse gas accounting systems are shown in Table 3.1.

Table 3.1: Comparison of Greenhouse Gas Verification Systems between EU and China

Project		EU MRV Accounting System	China Accounting System
Emission reduction targets		By 2030, EU carbon dioxide emissions are expected to be 2% lower than baseline levels.	By 2015, carbon dioxide emissions per unit of gross domestic product will be 17% lower than in 2010.
M (Monitoring)	Monitoring objects	Ships of more than 5000GT in and out to and from 27 EU countries	Taking departments, enterprises and projects as objects, focusing on emission reduction technology and energy saving and emission reduction projects
	Data sources	Discharging Enterprises with Ports, Marine Ships and Other Emission Sources	With the help of the existing energy statistics, monitoring and assessment system
	Monitoring methods	1. Use thin fuel oil supply for monitoring 2. Monitoring fuel tanks 3. Use flowmeters suitable for combustion process 4. Direct Measurement by Continuous Monitoring System of Flue Gas Emission	Energy-saving and environmental protection monitoring network in transportation and navigation industry mainly relies on port monitoring stations
R (Reporting)	Submit report	1. Monitoring plan report 2. Annual monitoring record report 3. Verified and complete monitoring report	Submit the system of GDP energy consumption bulletin and publish energy saving information publicly
	Receiving reports	1. Submitted to recognized institutions of the European Union 2. Contents of reports submitted to third-party verification bodies	
	Content of the report	Accurate CO2 emissions from various sources	
V (Verification)	Verification bodies	Independent third-party institutions certified by the European Union	With the help of the existing energy statistics, monitoring and assessment system, energy audit is carried out, and the professional system of energy managers in transportation industry is established (under construction).
	Verification content	1. Implementation of monitoring plan 2. Specific monitoring data 3. Verification of Special Issues	
	Supervisory bodies	Port state	

3.2 Situation of MRV management of shipping company from company level

At present, the supervision of ship carbon emissions is still completed by water enterprises. Firstly, the cost of fuel consumption is the main part of the expenditure of ship operation. Enterprises have been constantly improving the monitoring and reporting of ship fuel for their own interests. Secondly, the amendment VI to the MARPOL Convention adopted by IMO introduced the rules of ship energy efficiency.

For the first time, the two standards of ship energy efficiency design index (EEDI) and ship energy efficiency management plan (SEEMP) were established as global mandatory carbon emission reduction rules, requiring all new ships with 400 gross tonnage or more to meet EEDI limits on January 1, 2013 and reduce carbon emissions by 10% and 2020. - In order to achieve the goal of reducing carbon emissions by 30% after 2024, shipping enterprises must complete the monitoring and reporting of ship carbon emissions in accordance with relevant requirements. Moreover, the transportation authorities of the Chinese government have also put forward relevant requirements for carbon emissions for domestic water transport enterprises, such as the "Twelfth Five-Year Plan for Transport Development" clearly pointed out that the energy consumption and carbon dioxide emissions per unit of transport turnover of operating ships in China have decreased by 15% and 16%, respectively. This also requires enterprises to do a good job in carbon emissions monitoring and reporting.

At present, the status quo of carbon emission management in international shipping industry is mainly limited to data monitoring and collection, and it has just started in China. However, for individual enterprises, energy conservation and emission reduction are consistent with the interests of enterprises, especially for large and medium-sized shipping enterprises, there are manpower and material resources to carry out energy conservation and emission reduction, carbon emissions control related work. Through investigation, we find that the work of shipping company in carbon emission management mainly focuses on the following aspects:

1. Actively respond to the relevant standards that have been issued. Due to the unsatisfactory performance of China's shipping ships in the design of energy efficiency index, nearly 50% of the ships need to be assisted by corresponding renovation measures to meet the benchmark of the ship energy efficiency design index (EEDI). By using the six-year policy grace period of "New Ship Energy Efficiency Design Index", waterborne enterprises have improved ship energy

efficiency and saved energy costs. Through upgrading and renovating ships, they have invested in low-carbon ship types, encouraged the development of transport ships with advanced technology, economic security, environmental protection and energy conservation, and accelerated the elimination of transport ships with backward technology, serious pollution and low efficiency, and the ship will become large-scale and inefficient. The direction of specialization and cleanliness is developing. At the same time, we will actively implement the Ship Environmental Index, Singapore Green Shipping Project, the Ship Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP).

2. Actively participate in the formulation of industry rules. At present, international carbon trading or carbon tax is a focus issue, and the first step to participate in carbon trading is to achieve enterprise and ship-level carbon emission MRV. Many water transport enterprises, especially COSCO Shipping Group, are among the top-ranking large-scale enterprises in the world. While actively implementing the requirements of international regulations such as ISO14064 and GHG Protocol, they will strengthen the collection and management of energy and emissions data, and actively participate in relevant national The formulation of the system, while using its influence to participate in the formulation of industry rules through channels such as industry organizations.
3. To formulate and optimize carbon emission management strategies for enterprises. Water transport enterprises are gradually assessing the costs and benefits of energy saving and emission reduction technologies for ships, formulating energy saving and emission reduction and carbon emission management plans suitable for their own conditions, and actively cooperating with relevant research institutes to continuously develop new technologies to improve ship energy efficiency.

3.3 The impact of MRV rules on shipping industry

First, it will cause changes in shipping costs.

1. Reduce operating costs. The operating cost of shipping enterprises is affected by many factors, such as fuel price, port fee, maintenance cost, depreciation cost, etc. The fuel cost accounts for 35-50% of the total operating cost. Implementing MRV rules in shipping industry can reduce fuel consumption and save fuel costs by improving the technical indicators and efficiency utilization of ships. According to the impact assessment report of EU shipping MRV program, by 2030, the annual cost of ship fuel on EU routes will be reduced by about 2% compared with the baseline. The cumulative cost of fuel will be saved by 5.6 billion euros in 2015-2030, and the average annual cost of fuel will be saved by 940 million euros per year.
2. Increased administrative costs. As an administrative measure, MRV will increase the administrative burden for ship operators. The establishment of MRV rules in China is facing the same pressure of administrative costs. Especially since the financial tsunami in 2009, China's shipping industry has been in a downturn. It is bound to produce resistance to MRV rules and become an obstacle to the establishment of MRV rules in China.
3. Export costs increased. China is a big trading country. It mainly depends on exports to promote its economic development. Most of its export products are low-end industrial chain products, which occupy the international market by virtue of price advantage. Taking container cargo exported to the United States as an example, ship emission reduction will make container ships and exporters pay more carbon emission costs of 180 million to 190 million US dollars, which will increase the burden of China's foreign trade and shipping industry development.

Second, this measure can also promote the development and application of energy-saving and emission reduction technologies. The proportion of old and old ships in the existing ship fleet of our country is relatively large, the technical level of old and old ships is relatively low, and the greenhouse gas emissions are large. Considering the operation cost and greenhouse gas emission reduction requirements,

CO2 emission reduction technology will become a new means for shipping enterprises to compete, transform technological advantages into economic advantages, and continuously develop energy-saving and emission reduction technologies to improve ship energy efficiency. We will speed up the elimination of old ships of excessive age, gradually avoid overdue service, promote the renewal of China's marine fleet, and greatly promote the low-carbon development of global shipping.

CHAPTER 4

INTERNATIONAL AND DOMESTIC MRV REQUIREMENTS FOR CARBON EMISSIONS FROM SHIPS

With the worldwide attention to energy conservation and emission reduction, IMO, EU and other organizations have carried out the control of ship carbon emissions. Some developed countries have not carried out carbon emission control for shipping enterprises because of their own interests. Our country attaches great importance to energy conservation and emission reduction of ships, and has carried out a series of work.

4.1 Data collection mechanism of IMO

Faced with the increasing environmental demands of the international community for low carbon transportation, IMO has shifted the focus of environmental protection to greenhouse gas emission reduction after solving SOx and NOx emissions and incorporating them into Annex VI of MARPOL Convention. In IMO negotiations on greenhouse gas emission reduction, European and American countries have taken a positive attitude to support the reduction of greenhouse gas emissions in shipping industry, and these countries have also put forward relevant suggestions on greenhouse gas emission reduction measures. IMO's measures to control greenhouse gas emissions are mainly embodied in technical emission reduction measures, operational emission reduction measures and corresponding supporting market mechanisms.

In terms of technical and operational emission reduction measures, MEPC 62 in July 2011 formally incorporated ship energy efficiency requirements into MARPOL Annex VI, and for the first time incorporated technical emission reduction measures (EEDI) and operational emission reduction measures (SEEMP) as mandatory requirements into the provisions of the Convention.

In terms of market mechanism, because the EU and the United States believe that IMO has made slow progress in market mechanism, the United States (MEPC 65/4/19) proposed a new proposal to establish new and old ship energy efficiency standards based on its original market mechanism measures, not as a market mechanism measure, but as an energy efficiency standard. And change the strategy, put the proposal under the requirements of technical performance and effectiveness. The new proposal mainly includes three stages:

Phase I: Data collection and analysis phase, including data collection and validation, benchmarking, establishment of energy efficiency standards, and acquisition of validation standards;

Phase II: In the demonstration phase, the ship will be assessed whether it can meet the set energy efficiency standards, but no compulsory compliance will be required. Continue to collect data to calculate cumulative energy efficiency values and determine whether revisions to energy efficiency standards are needed. MEPC is required to set up a ship classification system: A (exceeding standard at least X%), B (exceeding standard less than X%), C (below standard less than X%), D (below standard more than X%) and labeled in IEEC certificate.

Phase III: The full implementation phase, which begins after the enforcement of energy efficiency standards and the entry into force of amendments. If the ship fails to meet the standards, it will be restricted by the corresponding requirements.

Belgium, Canada, Denmark, Germany, Japan, Norway and the United Kingdom agreed with the phased proposal put forward by the United States. At present, IMO

focuses on the discussion of future technologies and operational measures to improve shipping energy efficiency, and takes the data collection mechanism of Phase I as the primary issue to be discussed and solved.

As for the international data collection mechanism, preliminary discussions have been held at recent MEPC meetings. At present, it is still in the process of further development, as follows.

Discussions at the 66th IMO Environmental Protection Conference (MEPC66):
In conjunction with Austria, Belgium and other EU member states, the European Commission has proposed the establishment of a global shipping emission/energy efficiency data collection system similar to EU MRV. Establish a framework to identify key elements of the mechanism. In response, the General Assembly established a working group to discuss the purpose, scope of application and key factors of the data collection system. And set up a communication group to work after the meeting. MEPC also encourages countries to voluntarily submit relevant data from any monitoring project and methodological test.

Discussions at the 67th IMO Environmental Protection Conference (MEPC67):
The communication group established by MEPC66 submitted a report on the work of the data collection system, which identified the core elements of the system and formed the overall framework of the data collection mechanism, including data collection, the role of flag States and the central database. However, no agreement was reached on such issues as the scope of data submitted and the frequency of reports. After considering the report of the Communications Group, the Committee agreed in principle that the current data collection system was a data collection system for fuel consumption. It was agreed to delete the relevant data requirements on "average annual operational energy efficiency" in the fuel consumption data collection system, while the provisions on "total annual transport volume", "total annual voyage

distance" and "total annual service time" were retained for consideration at the next session, at which a communication group was set up again to improve the content of the data collection mechanism.

Discussion on the 68th IMO Environmental Protection Conference (MEPC68):

At MEPC 68 in May 2015, the Communications Group submitted a draft text of the data collection mechanism as required. Some of the issues in the draft are data transfer when changing owner or flag, and whether data verification and port state inspection are needed. After consideration of the draft text, the Committee was unable to reach agreement on some identification issues (e.g. whether the mechanism should be mandatory, transport parameters (cargo volume, voyage distance, heating or refrigeration, etc.). At the end of the meeting, no decision was made as to whether the data collection mechanism should be mandatory or voluntary, but it was agreed that: For international ships with 5,000 GT or above; There should be a method of collection and reporting in SEEMP and the SEEMP should be resubmitted for review. The responsible party is the flag State authority (or its accredited organization). The annual certificate of conformity of the ship shall be verified, and the PSC shall check the certificate of conformity. The content of data collection is determined as: Annual fuel consumption for all use on board; The main parameters of a ship include ship type, total tonnage/net tonnage, load tonnage, main and auxiliary engine power, design speed, EEDI (if applicable) and ice grade (if applicable). In order to speed up the legislative process of data collection mechanism at IMO level, the Committee decided to hold an inter-meeting of data collection system working group between two MEPC meetings to discuss further the establishment of data collection mechanism in order to achieve substantive progress and report to MEPC69.

Discussion on the 69th IMO Environmental Protection Conference (MEPC69):

In September 2015, a working group meeting on MRV data collection mechanism was held at the 69th session of MEPC. The data content, data confidentiality and related

guidelines were discussed, and the design tonnage of ships was used as an alternative parameter to the actual cargo volume.

Discussion on the 70th IMO Environmental Protection Conference (MEPC70):
In 2016, the 69th session of IMO MEPC finally approved the global oil consumption data collection mechanism for ships, which was formally adopted at the 70th MEPC meeting. It was proposed that SEEMP for ships with 5,000 gross tonnage and above should include the data collection methods and data reporting authority procedures required by MARPOL Annex VI22A by 31 December 2018. The company (ship) should be on 1 January 2019. In each calendar year thereafter, data shall be collected for ships of 5,000 gross tonnage or above in accordance with the methods prescribed by SEEMP. Within three months after the end of each calendar year, ships shall report data to the competent authority or its authorized organization by electronic communication in a standard format established by IMO.

4.2 MRV requirement of EU

4.2.1 Related background

After nearly two years of deliberation, discussion and amendment, the EU Maritime MRV Bill was formally adopted by the European Parliament and Council at the end of April 2015 and released under the name of "Regulation 2015/757 on Carbon Dioxide Emissions, Reporting and Verification in Shipping of the European Parliament and Council". The Regulation will come into force on July 1, 2015 and begin its first monitoring cycle on January 1, 2018. The EU MRV Regulation establishes a framework for monitoring, reporting and validating greenhouse gas emission data from shipping. However, how to implement the relevant requirements has not been clearly defined. In the follow-up, relevant regulations will be formulated by the

European Commission. At present, based on ESSF (European Forum on Sustainable Shipping Development), the EU is setting up two working groups on monitoring and verification, which will absorb experts from various countries and relevant institutions, and further discuss the specific issues of monitoring and verification implementation in MRV regulations, which will serve as the basis for subsequent EU decrees.

4.2.2 Introduction of EU MRV requirements

At present, the MRV regulations only deal with carbon dioxide emissions from all fuel combustion on board ships, excluding other greenhouse gases for the time being; they are applicable to all ships with a total tonnage of more than 5,000 entering and leaving ports of EU member countries and sailing between ports of one EU member country, without distinction between flag and owner. Except for military vessels, fishing vessels, non-motorized vessels and official vessels.

Shipping companies/shipowners will be responsible for the implementation of MRV regulations. The specific implementation of the Regulations is as follows:
The ship owner proposes a monitoring plan and monitors the fuel consumption, carbon dioxide emissions and related information of each voyage according to the plan, then monitors the voyage and reports the monitoring results annually. The third-party certification authority shall verify the monitoring plan, verify the emission report and issue the conformity certificate. The emission report will be submitted to the European Commission and relevant authorities after verification. The European Commission publishes relevant data on emissions and so on. The competent authorities of the port state shall check whether the arriving vessels comply with the requirements of the MRV Regulations. Punishment and sanction measures shall be implemented by EU member states. The implementation process of the MRV Regulation is shown in Figure 4.1.

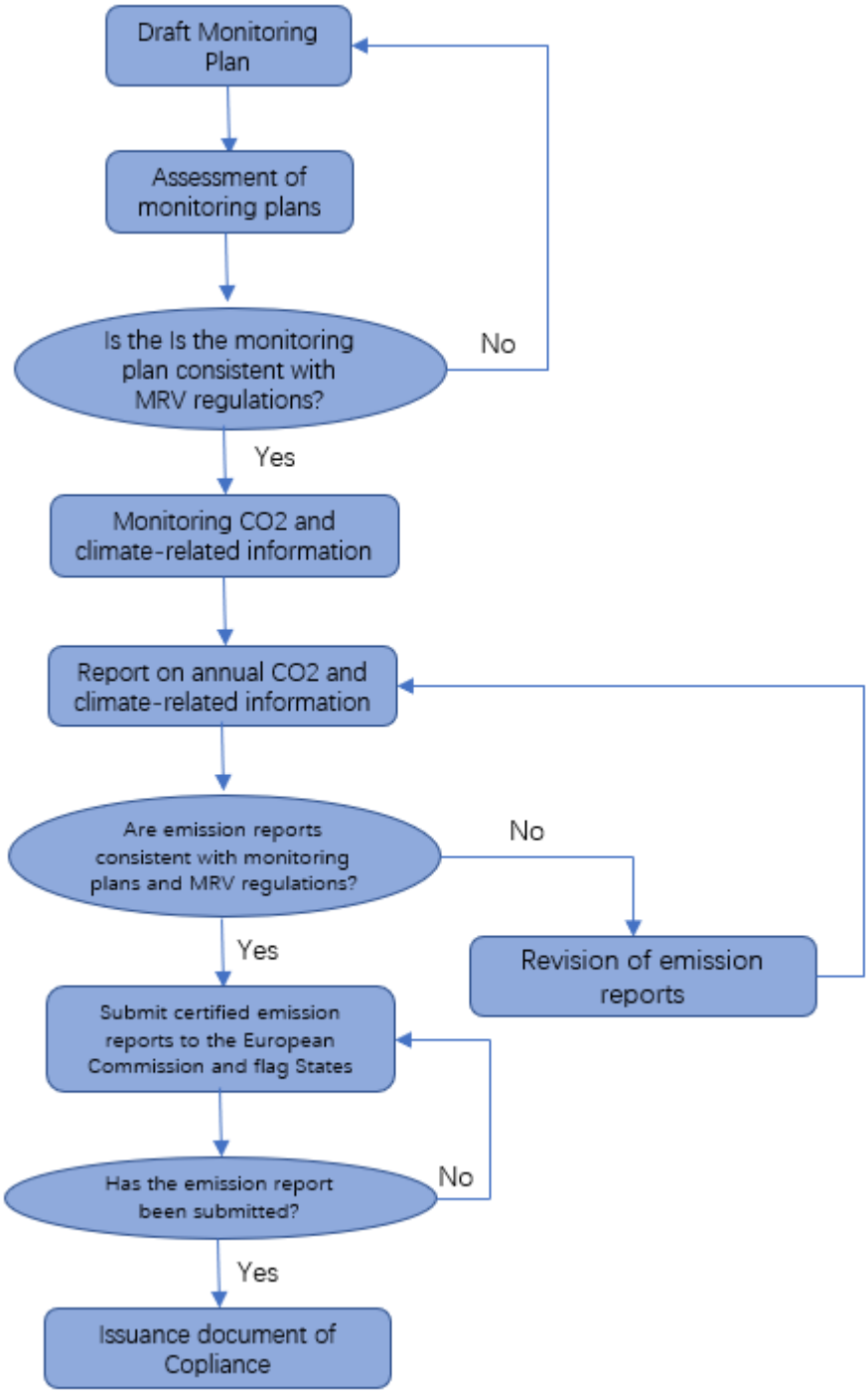


Figure 4.1: EU MRV Regulation Implementation Process

Monitoring methods of fuel consumption/emission:

For monitoring fuel consumption/CO2 emissions, the MRV regulations provide the following four ways:

1. Bunker delivery Note (BND): There is little cost increase, but the scope of use is

limited. It is not suitable for vessels entering and leaving the EU and cargo-fueled vessels (such as LNG ships), and the accuracy is poor.

2. In-tank oil level monitoring: Simple monitoring method, equipment cost is relatively low, can be monitored manually or electronically. But the accuracy varies according to the structure of the ship and the use of the software.
3. Flowmeter monitoring: It can achieve high accuracy and is easy to monitor separately within and outside the EU, but the cost of equipment is high.
4. Direct carbon dioxide emission measurement: High accuracy and high cost. The shipowner lacks experience in use. Using this monitoring method, other gas emissions can be measured simultaneously, which may be helpful for the follow-up implementation of MVR regulations.

The report requires that, starting in 2019, by April 30 each year, shipping companies should submit emission reports and related information validated by certificators to the European Commission and flag State authorities within a monitoring period (one year). The main contents covered by the report requirements are as follows:

1. Specific information about the ship and its owner;
2. Port information;
3. Technical Energy Efficiency Index (EEDI or EIV);
4. The monitoring methods used and the corresponding uncertain information generated;
5. Data and parameters obtained from annual monitoring.

The verification process will be carried out by independent third-party bodies (such as classification societies and other flag State certification bodies), whose tasks include:

1. Audit the conformity of the monitoring plan with the MRV regulations;
2. Audit whether the shipowner monitors according to the monitoring plan;
3. Check whether the emission report has been completed in accordance with the provisions of the MRV Regulations;

4. Issuance of Document of Compliance.

In the long run, the MRV regulation is the first step of the EU's "three-step" strategy for reducing greenhouse gas emissions from shipping. By collecting relevant emission data, the next stage will set emission reduction targets and establish baselines based on the collected data. Finally, the shipping emission reduction market mechanism (MBMs) is implemented. Therefore, the MRV regulation can be regarded as a prelude to the implementation of the Market-Base Measure of shipping emission reduction in the EU, and also an important way to implement the Market-Base Measure of shipping emission reduction. At the same time, the EU has spared no effort to promote emission monitoring, reporting and verification mechanisms to the International Maritime Organization (IMO). At the 68th IMO Environmental Protection Association (MEPC68), EU representatives carried out propaganda and promotion with the approved MRV regulations in order to internationalize their mechanisms or to accelerate the legislative pace of the global emission monitoring, reporting and verification mechanism. At that time, this mechanism will not only be regional laws and regulations, but also will further expand the impact on shipping enterprises.

4.3 MRV requirement of other countries

4.3.1 U.S.A.

Carbon emission MRV in the United States started earlier, including the well-known mandatory greenhouse gas reporting system. (greenhouse gas reporting program-GHGRP)，But it mainly concentrates on the electricity, construction and other industries in the United States. Considering their own interests, MRV for carbon emissions of shipping enterprises has not been carried out, but energy consumption of ships has been regulated under the framework of IMO. The Maritime Authority under the United Stated Department of Transportation established its own emission baseline

as early as 2008 and updated its emissions annually to identify carbon footprint changes and identify emission reduction opportunities. The US Environmental Protection Agency (EPA) indirectly manages carbon emissions from the shipping industry at the greenhouse gas reporting and fuel levels, leading the development and implementation of renewable fuel standards to ensure that all transportation fuels sold in the United States contain a minimum proportion of renewable fuels. EPA is also responsible for the statistics and accounting of carbon emission data in the transportation industry. According to its published data of carbon emission in the transportation industry from 1990 to 2010, domestic ship emissions have reached a peak in 2000 and are currently fluctuating at a relatively low level. EPA also counts fuel consumption for international shipping, although these emissions are not included in the U.S. national greenhouse gas inventories.

4.3.2 Japan and South Korea

Japan's shipping policy trends are mainly reflected in their positive contributions and subjective initiative in supporting IMO in formulating GHG emission restrictive system in the shipping industry. As a big country in shipbuilding industry, Korea is mainly concerned with the formulation and initiative of new standards for new shipbuilding technologies, such as low-energy ships. Neither of the two countries has carried out MRV work on ship carbon emissions in their own countries.

In July 2011, IMO introduced the first global GHG emission regulation for ocean transportation in the form of amending Annex VI of MARPOL Convention (which came into effect on January 1, 2013). It should be said that this regulation is basically based on the blueprint designed by the Japanese government, which reflects the interests and aspirations of the Japanese government. On September 6, 2011, the Japanese government adopted an amendment to the Law on Marine Pollution and Marine Disaster Prevention by virtue of almost all references. This regulation of IMO

was changed into domestic law (which came into effect on January 1, 2013). Japan's leading role in IMO is also reflected in the control of the position of "IMO Secretary-General", the top head of the International Maritime Organization (Koji Sekimizu). Kitack Lim, president of Pusan Harbour Commune from South Korea, was elected as the new IMO Secretary-General on 30 June 2015.

4.4 MRV requirement of China

From the above, we can see that China has not carried out MRV work on ship carbon emissions, but at the national level, there are clear requirements for ship energy saving and emission reduction. Enterprises have actually carried out part of MRV work on ship carbon emissions. China's transport sector has set up greenhouse gas emission reduction schemes for the shipping industry. On the one hand, by implementing the "Twelfth Five-Year Plan of Transportation" and formulating national standards such as "Limit Value and Verification Method of Fuel Consumption for Operating Ships" and "Limit Value and Verification Method of CO2 Emission from Operating Ships", we will gradually guide enterprises to transform to low-carbon technology with policy orientation. On the other hand, the implementation plan of eliminating backward production capacity and transportation capacity is formulated, and the domestic ship design rules similar to EEDI are studied and formulated to guide enterprises to improve low-carbon energy-saving technology. Through the compulsory provisions of the state, provisions similar to the "General Rules for Green Ship Dismantling" or "Hong Kong Convention" are introduced to obviate backward capacity or capacity and reduce greenhouse gas emissions in domestic industries. And China has also established a domestic greenhouse gas emission reduction trading system. At present, China has launched carbon emissions trading pilot projects in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong and Shenzhen. Tianjin, Shanghai, Guangdong and Shenzhen have developed shipping industries. Some cities have considered incorporating shipping industry into the carbon emission trading system, clarifying the basic rules of carbon emission trading

in local shipping industry, and using market mechanism to reduce the total cost of shipping emission reduction. (Springer Nature,2013)

The levy of domestic maritime carbon tax is also one of the important directions of domestic policy development in the future. The EU imposes corresponding maritime carbon tax in accordance with WTO principles, but double taxation violates WTO principles. If the relevant carbon tax is levied first in China, the EU will violate the principles of WTO if it is levied again. Although marine carbon tax increases the cost of enterprises to a certain extent, it can effectively promote the innovation of new technologies and increase the international competitiveness of the whole industry. At the same time, the tax and fee levied can be reimbursed to enterprises in a certain proportion to minimize the cost of emission reduction.

CHAPTER 5

MRV METHODOLOGY AND RELATED TECHNOLOGIES

5.1 Energy efficiency measurement method for operating ships

From the current GHG emission reduction measures, its development focus is shifting from the previous market mechanism to MRV mechanism. The MRV mechanism of shipping greenhouse gas emissions intends to collect data through MRV, and on this basis, establish energy efficiency baseline and set emission reduction targets. For the establishment of the baseline of the operating ship, it is necessary to adopt a suitable method to measure the operational energy efficiency. The application of the method will greatly affect the follow-up emission reduction work.

At present, in addition to the EEOI method proposed and used in SEEMP, IMO has proposed four energy efficiency measurement methods. The first three are related to operational data.

1. The mode recommended by the United States (fuel consumption (joule)/transport power (operating time);
2. Annual EEOI;
3. Independent Ship Performance Index (ISPI);
4. Fuel Oil Reduction Strategy (FORS).

5.1.1 Proposed measures by the United States

The United States has proposed a new proposal to establish energy efficiency

standards for old and new ships. This measure achieves overall energy efficiency by calculating fuel consumption, mileage, cargo (passenger) volume and other relevant operational information in the operation of ships (2000GT and above for calculating the type of ships suitable for Attained EEDI) and calculating the overall energy efficiency according to the following formulas.

$$\text{Attained Overall Efficiency} = \frac{CO_2 \text{ Emitted from Fuel Consumed during the Period}}{\text{Cargo Carried or Work Done during the Period}}$$

$$CO_2 \text{ Emitted from Fuel Consumed during the Period} = \sum_j FC_j \times C_{Fj}$$

Transport work = voyage X cargo load. However, in the proposal of MEPC65, the United States further amended its method: carbon dioxide emissions (gCO2/ton.nmile) were replaced by fuel consumption (joule). Transportation function is replaced by operating hours. Therefore, the data to be collected include: Fuel consumed; Operation time; Other basic data, such as ship name, IMO number, load tonnage, etc.

5.1.2 Annual EEOI

Considering that the IMO has mandatory requirements for SEEMP, and based on IMO MEPC.1/Circ.684 circular, EEOI can be used as a measure of energy efficiency. However, considering the volatility of EEOI of a single voyage, it is suggested to use annual EEOI value as a measurement standard. Fuel consumption, navigation distance and DWT are taken as the basic parameters for calculation. (Unlike MEPC.1/Circ.684, the original EEOI guidelines used actual cargo volume as a calculation parameter).

The advantages of using annual EEOI are: It has the same measurement as EEDI (g-CO2/tonne-mile). Since EEDI is targeted at new shipbuilding within a certain range, and EEOI can be applied to all types of new or existing ships, consistency between the two methods of CO2 emission reduction can make future assessment more accurate and fair, while increasing the effectiveness of the policy framework. In

the SEEMP Guidelines (MEPC. 213 (63)), the suggestion of using EEOI as a monitoring tool to monitor the actual energy efficiency of ships is given. Its monitoring and calculation details are given in MEPC.1/Circ.684 in 2009. With the entry into force of MARPOL Annex VI, EEOI has been used by shipowners and operators worldwide.

The annual EEOI formula is:

$$\text{Annual EEOI}(g\text{-}CO_2 / tonne\text{-}mile) = \frac{\sum_j FC_j * C_{Fj}}{DWT * D}$$

From the point of view of the formula, the ship needs to provide three aspects of data in operation: fuel consumption; navigation distance; Load tonnage; DWT value for EEDI calculated by ships (e.g. 100% DWT for liquid cargo ships and 70% for container ships);

Although the MARPOL Annex VI already requires the ship to have a fuel supply list (BDN). However, BDN does not provide actual fuel data, so it may need to increase the corresponding measurement equipment to obtain more accurate fuel data.

Navigation Distance: The ship's position can be obtained by using the navigation log or converted to the navigation distance. Navigation system can also be used to record the actual distance of navigation.

Cargo volume: The actual cargo volume may be difficult to obtain or increase the workload of data acquisition. It is suggested that the DWT value for EEDI should be calculated by ships (such as 100% DWT for liquid cargo ships and 70% for container ships).

Therefore, in general, there is no technical difficulty in parameter collection and acquisition. And collecting data in the above way does not require additional operating costs, and the management burden is low.

5.1.3 Independent ship performance index (ISPI)

This method can be combined with the energy efficiency of ship design and operation.

Firstly, the data of fuel consumption, navigation distance and fuel type were collected in 2-3 years. Then the Estimated Index Value (EIV) is calculated for a single ship and the baseline is returned. The EIV and EESV of single vessel were compared. The ratio of EIV to EESV is taken as a design energy efficiency parameter, and the deviation from the energy efficiency standard of this type of ship is taken as ship's specific Variance (Vc).

1. Standard Reference Design (curve value): Vc = EIV/EESV =1
2. Lower Efficiency Design(above curve value): Vc = EIV/EESV >1
3. Higher Efficiency Design (below curve value): Vc = EIV/EESV <1

When the baseline does not change, Vc is the fixed value, so the energy efficiency upgrading of operating ships is embodied in the "operational part".

IMO has formulated EIT, a comprehensive target for energy efficiency improvement. EIT= (Operational Energy Efficiency) X (Design Energy Efficiency Improvement Target% X Design Energy Efficiency Index) =[(Fc X Cf)/D] X (Y X Vc). Y is the design energy efficiency improvement target. If feasible, it can also increase the relevant parameters (such as cargo index) of the impact of global economic and market changes on ship operation. However, there is a lack of specific methods.

The parameters needed for calculating the index include: EIV (EEDI estimation), EESV (EEDI reference value), Fc (fuel consumption), Cf (carbon conversion coefficient), D (navigation distance); For EIV and EESV, these parameters can be obtained from Fairplay database as long as the main engine, design speed, load tonnage and the sample of the ship type do not change, and the EIV and EESV of the ship are fixed values. Fc, Cf and D can be obtained from nautical and fuel record books, fuel delivery orders, fuel quality sampling and testing, on-board measurements, electronic charts and other positioning systems. Although it is not difficult to obtain most of the calculation parameters of this index. However, the significance of this indicator is still worth further study. Different ships have different EIV/EESV, which means that for each ship, IMO must set different target values. In order to achieve this

goal, the design and operation energy efficiency of ships may be improved. However, the energy efficiency of ship design is involved in the indicators. New ships and existing ships built on January 1, 2013 and after have been controlled by EEDI standard system. Currently, the proposed indicators are mainly used to control the energy efficiency of ships built before January 1, 2013. The EIV and EESV of single ship are similar to the calculation of EEDI and the setting of baseline. Therefore, from this point of view, it is inconsistent with our country's position that ship design energy efficiency is not linked to existing ships. In addition, the index is only CO2 emissions per unit nautical mile, so it is obviously unreasonable to ignore the impact of cargo load on energy efficiency and CO2 emissions.

5.1.4 Fuel reduction strategy (FORS)

Firstly, this method proposes a specific fuel consumption benchmark for ships, and accordingly reduces the annual fuel consumption of ships. The reduction target is determined by IMO, and it is up to shipowners/ship operators to consider how to reduce fuel consumption. The simplicity of this mechanism is that it does not need to collect data to establish fuel consumption benchmarks, but uses the 2007 data in IMO GHG STUDY to calculate and act as a benchmark. At the same time, it is proposed that MRV mechanism should be adopted in the process of fuel reduction.

Fuel reduction strategy only controls CO2 emissions by controlling the total annual fuel consumption of ships. Firstly, the fuel consumption benchmark is determined by IMO data in 2007 GHG study, and the corresponding reduction targets are set according to the emission reduction capacity. Thus the annual fuel consumption standard of the ship can be obtained. The actual fuel consumption of ships is monitored and verified by MRV mechanism in operation. Fuel consumption standard = fuel consumption baseline value * (1 - reduction target). So under this mechanism, only the fuel consumption needs to be monitored. There will be no additional cost and

management burden.

In summary, the parameters required by the four measures mentioned above can be obtained from the existing data sources required by the Convention. There is no technical difficulty and no burden. If the accuracy of data needs to be improved, the main difficulty lies in the collection and statistics of fuel consumption. It may be necessary to add appropriate measuring equipment to obtain more accurate fuel usage data. As far as the monitoring of fuel consumption is concerned, the accuracy and reliability of the data obtained by using BDN and fuel record book are poor. At the same time, BDN is not suitable for ships using cargo as fuel (such as LNG ships). Other advanced data collection methods, such as flow meter monitoring and direct emission measurement, can be given due consideration. Of course, the corresponding equipment cost will increase proportionally.

5.2 Carbon emission accounting method

5.2.1 Overall method of carbon emission accounting

At present, the methods used in carbon emission accounting at home and abroad basically include emission factor method, material balance method and direct monitoring method.

1. Emission factor method is a method of multiplying the amount or output of raw materials, materials or fuels by a specific emission factor.
2. Direct monitoring is a method to monitor the exhaust gas composition directly by continuous emission monitoring or periodic sampling, to determine the emission concentration of greenhouse gases, and to calculate the greenhouse gas emissions according to the emission concentration and flow rate.
3. Material balance method is a method of calculating greenhouse gas emissions by balancing the input, output, consumption and conversion of mass and energy in production process or chemical reaction. The main purpose is to use material

balance method in some industries because of the special production process and the difficulty in obtaining suitable emission factors. For example, clinker production in cement industry (waste tire, waste solvent, mud burning agent), urea used in denitrification treatment in cement industry, consumption of electrode rods in electric arc furnace steelmaking, etc.

5.2.2 Emission accounting mothod of shipping company

For water transport enterprises, carbon emission accounting mainly adopts emission factor method. This is due to the limited space of ships and the need to ensure shipping safety. It is not appropriate to monitor greenhouse gas emissions directly on ships, and the applicability of direct monitoring method to waterborne enterprises is low. In addition, because ship emissions come directly from fuel combustion, there is no process emissions similar to industrial production, so the material balance method is not applicable to waterborne enterprises.

For the carbon emission factors of ships, IPCC, IMO and research institutions at home and abroad have proposed different emission factors, which can be classified into three types: IPCC parameters, IMO parameters and dynamic factors based on ship installed capacity. The first two methods are "top-down" thinking, that is, calculating emissions based on the multiplication of overall fuel oil consumption and emission factors. The last method belongs to the "Bottom-up" thinking, which is based on the main engine, auxiliary engine working time and load, average emissions per ton of sea mile and other factors.

1. IPCC parameters: The Intergovernmental Panel on Climate Change (IPCC) Emission Factor Database (EFDB) is a database of emission factors and parameters established to facilitate the assessment of greenhouse gas emissions and mitigation in various countries. Emission factors of IPCC are widely used in the field of greenhouse gas calculation. They are the emission factors adopted by

the European Union's carbon emission trading system (ETS), and are widely used in the carbon emission accounting of chemical industry, steel industry and other industries in China. In addition, Annex I-A of the EU Regulation on the Monitoring, Reporting and Verification of Carbon Dioxide Emissions from Maritime Transport and the Revision of Regulation No. 525/2013 (EU) also mentions that "monitoring fuel consumption and calculating the corresponding CO2 emissions through conversion: fuel consumption * emission factor = CO2 emissions, the default emission factor should be determined according to the latest IPCC values". According to the idea of IPCC, the formula for calculating the total amount of carbon dioxide emissions from ship fuel combustion is as follows: the product of different types of fuel activity level data and emission factors:

$$\mathrm{E} = \sum_{i} \mathrm{AD}_i \times EF_i$$

E is the total carbon dioxide emissions from ships (t);

AD_i is the activity level data of type I fuel (TJ).

EFi is the emission factor of fuel type I (tCO2/TJ).

i is Types of Fuels

2. IMO parameters: The following formulas can be used to calculate the carbon emissions of water transport enterprises:

$$\mathrm{E} = \sum_{\mathrm{i}} \sum_{\mathrm{j}} \mathrm{FC}_{\mathrm{ij}} \times \mathrm{C}_{\mathrm{fj}}$$

FCij is the consumption of fuel J in range I.

CFj is the conversion coefficient between fuel and CO2 of fuel J.

The FCij data source can be ship logs (bridge logs, engine logs, deck logs and other official records). CFj is a dimensionless conversion coefficient between fuel consumption (per g) and carbon-based CO2 emissions (per g). The CFj values listed in MEPC.1/Circ.684 are as see in Table 5.1.

Table 5.1: Conversion Coefficient between Fuel Volume and CO2 Volume

Fuel oil type	Reference	carbon content	CF(t-CO2/t-fuel oil)
1 Diesel/gasoline	ISO8217 DMC to DMX	0.875	3.206000
2 LFO	ISO8217 RMA to RMD	0.86	3.151040
3 HFO	ISO8217 RME to RMK	0.85	3.114400
4 LPG	Propane, Butane	0.819 0.827	3.000000 3.030000
5 LNG		0.75	2.750000

Source: IMO-MEPC.1/Circ.684

3. Dynamic factor: Dynamic factor is a commonly used method in calculating ship's air pollutant emissions. Its principle is to calculate pollutant emissions through the work done by main engine and auxiliary engine. The calculation principle of dynamic factors widely used in the world is shown in the following figure 5.1:

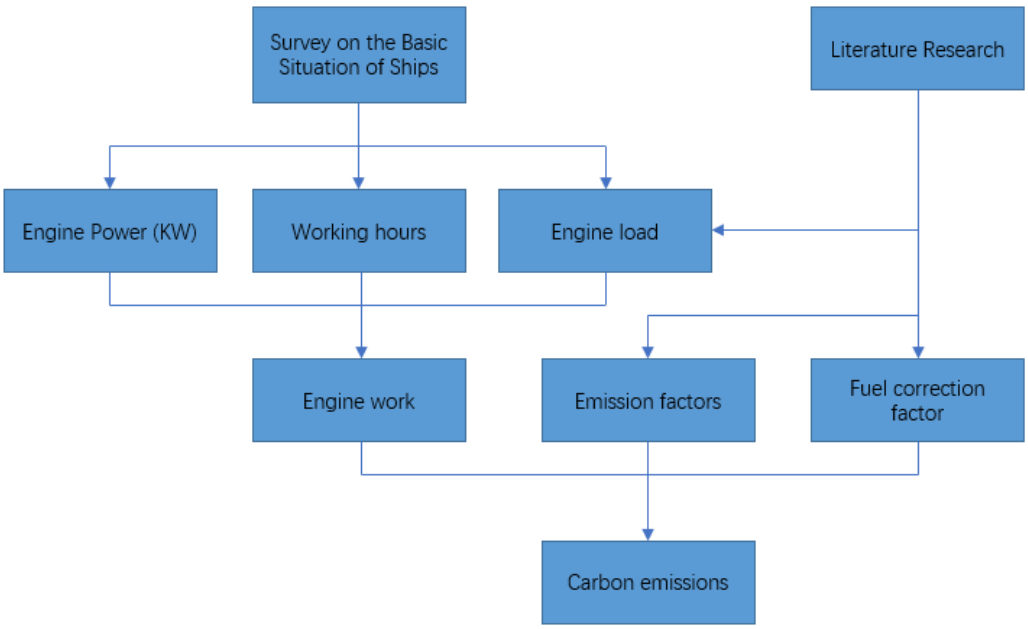


Figure 5.1: Principle of calculating dynamic factor

The formulas for calculating the dynamic factors are as follows:

Formula 1: Formula for calculating work done by marine engines

$$W = MCR \times LF \times Act$$

Among them: W = the work done by the ship (Kw.h)； MCR = engine rated power; LF = load factor (ratio of average load to maximum load); Act = working time;

Formula 2: Formula for calculating marine engine emissions：

$$E = W \times EF \times FCF \times CF \times 10^{-6}$$

Among them: E = emission (t/year); EF = emission factor (g/Kw.h); FCF = fuel correction factor; CF = emission control factor (changes after using emission reduction measures)

Formula 3: Emission Factor Correction Formula:

EF = base EF*LLA; where LLA = low load adjustment factor.

5.3 Carbon emission verification method for shipping company

5.3.1 Boundary selection

Verification agencies shall determine the boundaries of enterprises by means of document review and on-site visits. According to different purposes, boundary can be divided into organizational boundary and operational boundary.

1. Organizational boundaries： When the organizational boundaries are used to quantify greenhouse gases for enterprises, all possible ranges of greenhouse gas emissions will be generated. Organizational boundary setting is an appropriate way to show the boundaries of the organization completely and clearly in order to identify and quantify the emission sources. Therefore, different organizational boundary setting will affect the verification results of greenhouse gas emissions.
2. Operational boundary： The selection of operation boundary includes the

identification of emission boundary, emission facilities and sources. Verification agencies should confirm that the selection of operational boundaries meets the requirements and that enterprises have identified reasonable and accurate boundaries. Determining operational boundaries includes identifying and eliminating GHG emissions related to the organization's operations, and classifying them by direct, indirect and other indirect emissions. This includes choosing which other indirect emissions need to be quantified and reported. If the operating boundary changes, the organization should explain.

5.3.2 Emission source identification

The verification agency shall determine whether the identified emission sources are clear, accurate and comprehensive according to the emission source identification method in the Guidelines for Accounting and Reporting of Greenhouse Gas Emissions from Waterborne Enterprises.

5.3.3 Quantization method

According to the carbon emission quantification method provided in the Guidelines for Accounting and Reporting of Greenhouse Gas Emissions from Waterborne Enterprises, and according to the actual situation of enterprises, the applicability of the quantification method of greenhouse gas emissions selected by enterprises is verified. The verification body should confirm that the selection and use of emission units can reasonably minimize uncertainty and produce accurate, consistent and reproducible quantitative methods.

5.3.4 Quantized data

If greenhouse gas activity level data are used to quantify greenhouse gas emissions

and removal, enterprises should select and collect greenhouse gas activity level data according to the requirements of the selected quantitative methods. In the process of verification, the authenticity, accuracy and rationality of activity level data should be fully planned.

When enterprises use emission factor method to calculate greenhouse gas emissions, the selected emission factors can be divided into the following categories according to different sources:

1. According to the activity data, the data obtained from the sample detection are obtained.
2. Selecting emission factors in the region where the enterprise is located;
3. Selecting emission factors of the country where the enterprise is located;
4. Select internationally available emission factors.

Obtaining emission factors according to the test should conform to the relevant laws and regulations; Obtaining emission factors through consulting the literature should select the data published by the recognized influential database or official government website. In order to select emission factors, enterprises should give priority to detection methods and emission factors.

5.4 Carbon emission verification method for shipping company

At present, the shipping market is relatively depressed, and the pressure of energy saving and environmental protection is increasing worldwide. Therefore, energy saving and emission reduction has become an important goal and research direction for shipping enterprises to fulfill their social responsibility and achieve sustainable development. As a shipping company, active participation in MRV research can bring greater social benefits.

5.4.1 Providing methods and tools for carbon emission verification

Constructing the technical framework of carbon emission verification system for water operation industry in China, providing practical methods and tools for carbon emission verification in China, has important foresight, advancement and practicability. The software of "Carbon Emission Data Verification Management System for Ships of Water Transport Enterprises" developed by the authors interacts the traditional verification technology with the data verification management system, realizes the verification of the rationality and authenticity of the carbon emission activity data provided by the verification objects, standardizes the verification work, improves the verification efficiency, ensures the quality of the verification work, and provides carbon emission nuclear for China's water operation industry. Check to provide practical methods and tools.

5.4.2 Discharge Verification Criteria Affecting Water Operation Industry

The integrated management platform of ship carbon emission data in water operation industry can grasp the energy consumption and emission data of water operation industry, provide technical support for international negotiations, and meet the requirements of China, IMO and EU for the collection, monitoring, reporting and verification of ship carbon emission data. Making water transport emission reduction standards and related policies, using industry platforms for large data analysis, researching and establishing industry carbon emission baseline, formulating allocation schemes for carbon trading quotas for water transport enterprises, providing practical methods and tools for MRV and carbon trading in domestic water transport industry, has important practicability and popularization value. Provide technical support for China's participation in international maritime emission reduction negotiations and response to EU unilateral actions, and strive for China's voice in the formulation of international maritime emission reduction strategy

And the leading role will play an important role in the international water industry to formulate verification criteria for greenhouse gas emissions.

5.4.3 Improving Carbon Emission Management Level of Shipping Enterprises

The verification management system and data collection software participated in the development standardized the work of carbon emission monitoring, reporting and verification of shipping enterprises. Improve the quality of enterprise data reporting, ensure the validity of data, and promote the transformation of ship management mode. The energy efficiency and carbon emission management of water transport enterprises provide technical guidance, which meets the actual needs of enterprises. With operability and scientific, it can improve data quality and effectively improve energy efficiency and carbon emission management level of enterprises.

CHAPTER 6

SUMMARY and CONCLUSIONS

Based on the analysis of international background and other domestic horizontal industries, this paper points out that the Marine Environmental Protection Committee (MEPC) of the International Maritime Organization (IMO) has launched a ship energy efficiency management plan for ship carbon emissions, and has restricted ship carbon emissions by modifying the relevant annexes to the MORPOL Convention. The European Commission has promulgated a domestic monitoring system for carbon emissions from ships, which will come into effect on January 1, 2018. The Development and Reform Commission of the State Council of China has organized the compilation of accounting methods and reporting guidelines for greenhouse gas emissions in 14 related industries. It can be seen that it is the general trend to carry out MRV work for China's shipping enterprises in order to promote energy saving and emission reduction of ships, which is also in line with the interests of shipowners.

Although the shipping industry is one of the most energy efficient modes of transportation in the world, the carbon emissions per unit cargo are still operating at a high level, which can be seen from our data tracking survey. Domestic shipping enterprises, especially large-scale shipping enterprises, have invested a lot of manpower and material resources. Through cooperation with relevant scientific research institutes, they have begun to improve shipbuilding technology, optimize management methods and enhance new technology of ship navigation, so as to continuously improve ship operation efficiency and reduce ship energy consumption.

At present, IMO and EU have adopted more feasible measures, such as ship energy efficiency management plan and ship carbon emission monitoring methods, to gradually carry out the control of ship carbon emissions and improve the efficiency of ship energy conservation and emission reduction. Relevant organizations and countries have also conducted methodological research on carbon emission MRV, which provides technical support for more efficient and accurate MRV work.

There are already some foundations for developing MRV of marine carbon emission in China. Firstly, the work of ship energy efficiency plan and ship carbon emission monitoring carried out by IMO and EU provides a good reference for China to carry out MRV of ship carbon emission for shipping enterprises. Secondly, the energy saving and emission reduction work carried out by the Ministry of Transportation and other departments in recent years for water transport enterprises provides a good reporting basis for this MRV work. Furthermore, waterborne enterprises have been strictly monitoring the energy consumption of ships for a long time, with the aim of minimizing the operating cost of ships. This work has been carried out and continuously improved. The ship reporting system of waterborne enterprises provides a good basis for the verification and reporting of MRV of carbon emissions from ships of waterborne enterprises. Finally, China has carried out a pilot carbon trading system in relevant areas, and the preliminary carbon emission verification system provides a useful reference for the verification of this work.

There are still some difficulties in developing MRV for Marine Enterprises in China. These difficulties are mainly manifested in the following aspects:

1. The MRV work of China's shipping enterprises is different from IMO's ship energy efficiency plan and EU's ship carbon emission monitoring methods, and is different from other domestic industries. How to protect the interests and enthusiasm of shipping enterprises while doing well the MRV work of ship carbon emission is the focus of this MRV work.

2. The uncertainty of data mentioned in the EU's monitoring methods for ship carbon emissions is an important factor affecting the monitoring data. The EU has not given a clear method for determining the data in its published monitoring methods. How to solve this problem is the difficulty of MRV work for ship carbon emissions.
3. IPMVP, MRR of EU-ETS, AVR and its supporting documents, and How to Lie with Statistics, published by Darrell Haff, all point out that data fraud is an important factor affecting verification. How to screen the fraudulent data and improve the authenticity of the data is a key point of MRV work.
4. After carrying out the ship carbon emission verification and reporting system, how to verify the content of the verification and reporting is an important yardstick for success or failure of the work. Although many pilot areas in China have developed a third-party carbon emission verification system and passed a number of third-party verification agencies with corresponding qualifications, the inadequate verification methods, inaccurate or incorrect verification content are still the difficulties that plague the entire domestic carbon trading. This will also occur after the implementation of the ship carbon emission verification system.

To sum up, the MRV work for marine enterprises should do a good job in M (monitoring), R (reporting) and V (verification), improve the relevant system, and solve the methodological problems in related aspects, so as to truly implement and achieve results.

The emission of greenhouse gases is becoming more and more serious, which is related to the survival and future development of human beings. At the same time, behind the policies and regulations of greenhouse gas emission reduction is often the game and balance between different countries ‘politics. This issue has a decisive impact on the future development of developing countries. Therefore, the issue of greenhouse gas emission reduction has become a global focus of attention.As ships

emit greenhouse gases throughout their voyage, whether within the jurisdiction of flag, port or coastal States or in areas not controlled by any competent authority. Whether or not the shipping enterprises are voluntary or not, facing increasingly stringent forms of carbon emission regulation at home and abroad, they will have to change their own energy management concepts and modes.

Shipping enterprises actively participate in the research of carbon emission MRV technology, pointing out the direction for shipping enterprises to carry out energy saving and emission reduction, and break the bottleneck of development. Actively respond to the call of the state, improve the efficiency of ship energy utilization, achieve energy conservation and consumption reduction, save operating costs, and guide enterprises to transform to low-carbon energy-saving technology; At the same time, it is of great practical significance for shipping enterprises to adapt to the increasingly stringent international industry standards, enhance their international image, enhance their competitive advantages, and enhance the voice power of China in important organizations such as IMO and international trade associations.

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