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Research on Carbon Emission Accounting of Water Transportation

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Abstract. The issues of "carbon peak" in 2030 and "carbon neutral" in 2060 have become hot issues in China and have attracted the great attention of the whole society. As an important part of economic development, transportation has become the "hardest hit" by carbon emissions. In response to this phenomenon, China should strengthen the quality of waterway transportation, reduce carbon emissions in transportation, improve economic efficiency, and reduce environmental pollution. Carbon emission statistics and accounting is an important foundation for the work of "carbon peaking" and "carbon neutral", and is an important basis for policy formulation, promotion, assessment, and negotiation for compliance. Therefore, it is urgent to study the carbon emission accounting method for water transportation enterprises that is suitable for China's national conditions and in line with international standards. It is necessary to systematically review and study the current development of carbon emission accounting in the field of water transportation, and provide a reference for the establishment of a carbon emission accounting system for water transportation. Combining the actual situation of the domestic water transportation industry and international policy requirements, this paper analyzes the key issues of carbon emission accounting for Chinese water transportation enterprises in terms of accounting boundaries and accounting methods and puts forward accounting suggestions.

Keywords: Water transportation; low-carbon development; carbon emissions; carbon accounting.

1. Shipping Industry Emission Reduction Status

Through the development of waterways in recent years, waterway transport methods fully meet the requirements of China's low-carbon economic development. The consumption of energy for waterway transportation is relatively small, and the carbon emissions of waterway transportation only account for about 3% of global greenhouse gas emissions. The vigorous development of waterway transport can effectively alleviate the problems caused by carbon emissions to the environment, and effectively implement the concept of low-carbon and environmentally friendly economic development. In recent years, China has accelerated the improvement of the inland waterway transport network, and the waterway to bear the bulk of cargo transport continued to improve. 2020, the waterway freight volume reached 7.616 billion tons, exceeding the "three-year action plan" proposed target.

With the continued development of China's economic and social and international trade, as well as the deepening of the "public to water" process under the requirements of pollution reduction and carbon reduction, the scale of the water transport industry and the energy consumption is still on the rise. If carbon dioxide emissions from the water transport industry are not controlled, it will lead to a high peak of carbon emissions from the water transport industry and increase the difficulty of subsequent "carbon neutral", therefore, the water transport industry needs to seriously deal with the "carbon peak" and "carbon neutral" challenges. Therefore, the water transport industry needs to seriously address the challenges of "carbon peaking" and "carbon neutral".

A report commissioned by the International Maritime Organization (IMO) points out that CO2 emissions from shipping increased from 962 million tons in 2012 to 1.056 billion tons in 2018, and its share in global CO2 emissions rose from 2.76% in 2012 to 2.89% in 2018. emissions from

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maritime transport will likely increase by 250 percent from 2012 levels if left unchecked, which could hinder global goals to curb climate change.

To that end, the IMO set emissions reduction targets for the global shipping industry - a 40 percent reduction in carbon emissions from the fleet by 2030 compared to 2008; and at least a 50 percent reduction by 2050 compared to 2008. With the EU's European Green Deal and the promotion and realization of carbon neutrality, the EU has also put forward requirements for the international shipping industry, explicitly requiring shipping companies to reduce the annual average CO2 emissions per unit of transport activity of all ships by at least 40% by 2030. By 2030, ships must have zero emissions at their moorings.

2. Accounting for Carbon Emissions from Water Transportation

Carbon accounting is a measure of direct and indirect emissions of carbon dioxide and its equivalent gases from industrial activities to the Earth's biosphere and refers to a series of activities in which governments, enterprises, or related organizations implement data collection, statistics, and records of carbon emission-related parameters according to monitoring plans, and calculate and accumulate all emission-related data. Carbon emission accounting is an important basis for carbon neutral work and is an important basis for policy formulation, promotion, assessment, and negotiation for compliance. Therefore, it is urgent to study the carbon emission accounting method for water transportation enterprises' ships that is suitable for China's national conditions and in line with international standards. It is necessary to systematically sort out and study the current development of carbon emission accounting in the field of water transportation, and provide a reference for the establishment of a carbon emission accounting system for water transportation.

2.1 Water Transport Carbon Accounting Boundary

Defining the boundary of water transport carbon emission accounting is the basis for analyzing the changes and characteristics of water transport carbon emission, and for judging the target of water transport "carbon peaking" and the implementation path and action plan.

2.1.1 Ipcc's carbon emission accounting boundary for water transport.

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as "2006 Inventory Guidelines") issued by the Intergovernmental Panel on Climate Change (IPCC) have strict carbon emission accounting boundaries defined for various modes of transportation.

(1) Carbon emissions are carbon emissions generated from power fuels used for waterborne vessels. The definition of international water transportation carbon emission or domestic water transportation carbon emission (i.e. water transportation carbon emission in the national emission inventory, hereinafter referred to as "national water transportation carbon emission") is not determined according to the flag or ship's registration, but according to the departure and arrival ports of the ship's voyage.

(2) International water transport carbon emission refers to the carbon emission of the international voyage from one country's port to another country's port. International voyages include sea, inland lakes, and coastal waters. International water transport carbon emissions do not include carbon emissions from fishing vessels. International military water transport carbon emissions may be listed separately as a subcategory when data is available to support it.

(3) National water transport carbon emissions are carbon emissions from fuel used by vessels on voyages where both the port of departure and the port of arrival are domestic ports, and do not include carbon emissions from fishing vessels.

The "national water transport carbon emission accounting boundary" in the 2006 Inventory Guidelines can be summarized as the carbon emissions of all vessels, except fishing vessels, whose ports of departure and arrival are both domestic ports, so national water transport carbon emissions can be divided into two parts.

(1) Carbon emissions from domestic voyages of all vessels of this nationality.

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(2) Voyage carbon emissions of all ships of international voyages whose ports of departure and arrival are both home ports.

The above method of delineating the national water transport carbon emission accounting boundary lays the foundation for the implementation of water transport carbon emission management in port countries. 2006 Inventory Guidelines (revised version) adopted by the 49th Plenary Session of IPCC in May 2019 maintains the same accounting boundary for various modes of transport emissions.

2.1.2 China's national water transport carbon accounting boundary.

China's national greenhouse gas inventory is based on a series of inventory guidelines and supporting documents issued by the IPCC, but the accounting boundary for water transportation greenhouse gas emissions used in the inventory does not meet the requirements of these documents issued by the IPCC.

The accounting method used to account for China's carbon emissions from water transportation in 2005 was: the GHG emissions generated by China's domestic vessels consuming 4.473 million t of diesel fuel and 7.617 million t of fuel oil as the emissions of all Chinese domestic vessels; the sum of domestic bunkering of Chinese international vessels and foreign international vessels bunkering in China (i.e. 3.68 million t) as the emissions of all international The sum of the bunkering volume of Chinese international vessels in China and the bunkering volume of foreign international vessels in China (i.e. 3.68 million t) is used as the voyage fuel consumption of all international vessels whose ports of departure and arrival are in China, and the voyage carbon emissions of all international vessels whose ports of departure and arrival are in China are calculated in this way.

In the above accounting, the carbon emission accounting of all Chinese domestic vessels complies with the requirements of IPCC inventory guidelines, but the bunkering volume of Chinese and foreign international vessels in China is taken as the voyage fuel consumption of all international vessels whose ports of departure and arrival are both Chinese ports, and the voyage carbon emission of all international vessels whose ports of departure and arrival are both Chinese ports is calculated based on this, which is not in line with IPCC's water transportation carbon emission accounting boundary requirements. The reason is that both Chinese and foreign international ships bunkering in China are only partially consumed in the voyage where both departure and arrival ports are China's ports, while both Chinese and foreign international ships bunkering outside China are partially consumed in the voyage where both departure and arrival ports are not China's ports.

Since water transport GHG emissions account for a very small percentage of the overall national GHG emissions, the deficiencies in the water transport GHG emissions accounting methodology do not have a significant impact on the national emission inventory results, and therefore the same water transport carbon emissions accounting methodology as that used for the 2005 China GHG inventory was still used for 2010, 2012 and 2014 China GHG inventories.

To achieve China's "carbon peak" target by 2030, the Ministry of Ecology and Environment has organized and prepared the "Guide for the Preparation of Provincial CO2 Emission Peak Action Plan (Draft for Comments)" (hereinafter referred to as the "Draft for Comments"). The "Accounting Boundary" of carbon emissions is clarified in the section of the "Exposure Draft".

Regarding the carbon emission accounting boundary of water transportation, the "Draft for Public Comments" requires each province (district or city) to include the carbon dioxide emissions of domestic sailing vessels of ship transport enterprises in the total carbon dioxide emissions of the province (district or city) where they are located according to the principle of the place of registration of operating entities; the total carbon dioxide emissions of international sailing vessels of ship transport enterprises are separately reported to the Ministry of Ecology and Environment. This practice is to count all carbon emissions of China's shipping enterprises into China's water transportation carbon emissions, and this water transportation carbon emissions accounting

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boundary does not meet the water transportation carbon emissions accounting boundary requirements of IPCC.

2.2 Water Transport Carbon Accounting Method

2.2.1 Calculation of CO2 emissions from ships.

Total CO2 emissions from international shipping can be calculated by the top-down fuel method. Calculating CO2 emissions from ships by the fuel method to calculate CO2 emissions from ships based on the consumption of various fuels in a certain period, the core of which is to calculate the consumption of various fuels and to select the carbon conversion factors corresponding to various fuels. The CO2 emissions of a ship calculated by the fuel method at a certain time are equal to the sum of the product of the consumption of various fuels of the ship and the carbon conversion factor corresponding to the fuels. The carbon conversion factor of a fuel can be calculated by using the mass fraction (carbon equivalent) of carbon in the fuel and the mass ratio of carbon to oxygen in the CO2 molecule. The carbon content of the fuels loaded on ships varies around the world, so the carbon conversion factor is best provided by the fuel supplier for greater accuracy. Currently, the fuel grades used in ships are standardized and the carbon conversion factor is relatively fixed for each fuel.

The advantage of the fuel method is that the relevant data are easier to obtain and the calculation method is simple. The disadvantage is that not all the carbon in the fuel is fully burned and converted into CO2, but also into other carbon-containing substances such as CO and black carbon; some fuel is not burned and escapes from the engine, forming sludge, oil sludge, or other substances, which are deducted in the statistics, but cannot be fully accounted for. The CO2 emissions calculated by the fuel method are often large. Therefore, the CO2 emissions from ships calculated by the fuel method have some errors, and the fuel method cannot reflect the spatial distribution characteristics and time change characteristics of carbon emissions from ships in real-time.

2.2.2 No authoritative source for waterborne fuel consumption.

In our country, except for the railroad transport mode, other transport modes are difficult to effectively count the actual amount of transport work done. Because of the diversity of other modes of transport operators, the actual amount of energy consumption corresponding to the amount of transport workload, and closely related to the operating costs of the operators, is more difficult to effectively count.

The Ministry of Transport according to the scope of responsibility can only publish the statistics of water transport cargo turnover, can not count the water transport energy consumption corresponding to the water transport cargo turnover, China also does not have other legal institutions responsible for statistical water transport energy consumption, therefore, for a long time "China Traffic Statistics Yearbook", the water transport industry "fuel consumption" section "Average consumption per 1,000 kilowatt-hours" and "Average consumption per 1,000 tonne-kilometers" are the 2 index values open to the sky. There is no statutory or authoritative source of domestic water transport fuel consumption, which is the basis for greenhouse gas or carbon dioxide emissions in national emission inventories.

2.3 Improve China's Water Transportation Carbon Emission Accounting System

At present, China's water transportation has not yet formed a mature carbon accounting method, and there are bottlenecks such as unified accounting boundaries, messy accounting methods, and lack of systematic management, which need to be solved.

2.3.1 Integrating international navigation into our water transport carbon accounting boundary.

In fact, both the departure and arrival ports of international voyages are the voyage fuel consumption of China's ports, which are closely related to China's foreign trade cargo throughput and the transportation organization of international voyages; the supply of bonded fuel in China is

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closely related to the management policy of China's bonded fuel supply, and the time of change of both is not synchronized and the degree is not the same.

In recent years, the management policy of China's bonded fuel supply has been adjusted and improved substantially, which has enhanced the economy of production and supply of bonded oil for Chinese enterprises. Coupled with the implementation of the worldwide energy conservation and emission reduction and International Maritime Organization (IMO) policy on sulfur emission limitation of ships in 2020, the internal economic circulation and further market opening competition pressure caused by the US crackdown on China, the market credit crisis triggered by the bankruptcy of Singapore's oil giant Hing Lung Trading, and China's recovery from the epidemic in the first place, the combination of these factors has further promoted the bonded oil business in China counter-trend growth. since 2017, China's bonded oil has grown rapidly, to 16,717,100 tons in 2020, an annual increase of up to 39.79%; in the first half of 2021, China's bonded oil supply was 9.8 million tons, an increase of 43.79% year-on-year.

With China's bonded oil supply replacing the fuel consumption of all international voyages where both the departure and arrival ports are China's port voyages, the growth momentum of China's water transport emissions thus determined will increasingly fail to represent the emissions of all international voyages where both the departure and arrival ports are China's port voyages.

The inconsistency between the national shipping emission accounting boundary and IPCC requirements will lead to problems of related international exchange and carbon emission management, and to avoid related problems, it is recommended that the concept of carbon emissions from water transport in line with international norms be adopted regardless of the preparation of China's GHG inventory or carbon peak action program.

In theory, the global mechanism for collecting data on ship fuel consumption, approved by the 70th session of the IMO Marine Environment Protection Committee (MEPC) in October 2016, requires international vessels of 5,000 gross tons and above to collect and report fuel consumption in a monthly calendar year cycle starting from January 1, 2019, to obtain for port states the voyage of international vessels whose ports of departure and arrival are both their ports This provides the conditions for port states to obtain the fuel consumption of ships on voyages where both the port of departure and the port of arrival for international voyages are their ports and to calculate the national water transport arrangements accordingly.

2.3.2 Calibrating carbon accounting results using census and monitoring information analysis.

There are two main accounting methods for carbon emissions in the transportation industry, one is the top-down method, which is measured by the national level based on the supply based on the energy balance sheet; the other is the bottom-up method, which is based on the industry level or the enterprise level and is measured from the bottom up based on the activities of vehicles, ships, trains, and airplanes. The bottom-up method uses all types of transportation vehicles as the main energy users for energy consumption statistics, i.e., the total carbon emissions generated in the transportation operation phase are calculated based on the passenger and freight turnover and the corresponding emission factors released by statistical agencies at all levels, with the following formula.

$$Q=\Sigma ni=1Si\theta i \quad (1)$$

Where: Q is the total amount of $CO2$ emissions; Si is the passenger and freight turnover of the ith mode of transportation; θi is the emission factor per unit of turnover of the ith mode of transportation.

The "bottom-up" approach, which studies the quantitative relationship between traffic volume, mileage, vehicle type, natural factors, and other micro-influencing factors and carbon emissions, generally calculates transportation carbon emissions based on the activity level (e.g., mileage) of each transportation mode multiplied by the carbon emission factor per unit activity level. In addition, there are also calculations of transportation carbon emissions based on the whole life cycle, a method that requires calculating the total carbon emissions generated throughout the life cycle of

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each type of transportation, including production, operation, and recycling. Compared with the "top-down" method, the "bottom-up" method can calculate the carbon emissions of different modes of transportation separately, statistically analyze the characteristics and trends of carbon emissions of different modes of transportation, and provide data support for policy formulation. However, there are differences in the energy consumption per unit of turnover of various means of transportation under different working conditions and transportation conditions, and a uniform value is often used in the actual calculation, which may lead to large errors in the large-scale calculation.

Given that the Ministry of Transport publishes statistics on waterborne cargo turnover, there is no statutory department to count the energy consumption of ships corresponding to waterborne cargo turnover. If the energy consumption per unit cargo turnover of a ship can be determined, the total fuel consumption of a ship can be determined. However, the energy consumption per unit cargo turnover of ships is closely related to the management level of ship operators, ship type, ship age, ship scale, etc., and it varies greatly.

In 2013, the relevant parties monitored the average energy consumption per unit cargo turnover for different marine cargo ship types and found that the average energy consumption per unit cargo turnover for liquefied gas ships, other liquid cargo ships, general cargo ships, other general cargo ships, multi-purpose ships, container ships, dry bulk carriers, and oil tankers was 48.7 kg of standard coal/kiloton nautical mile, 24.8 kg of standard coal/kiloton nautical mile, 13.4 kg of standard coal/thousand-tonne nautical mile, 10.1 kg of standard coal/thousand-tonne nautical mile, 8.4 kg of standard coal/thousand-tonne nautical mile, 7.0 kg of standard coal/thousand-tonne nautical mile, 4.6 kg of standard coal/thousand-tonne nautical mile and 3.7 kg of standard coal/thousand-tonne nautical mile, respectively. Therefore, it is difficult to adopt regional statistics of energy consumption per unit cargo turnover of ships, energy consumption per unit cargo turnover of certain types of ships, or energy consumption per unit cargo turnover of ships of some shipping companies to replace the national energy consumption per unit cargo turnover of ships with logical conviction and technical feasibility.

In 2008, the Ministry of Transport organized a special survey on the national waterway transport volume, using a large amount of data obtained from the "bottom-up" survey to conduct statistical analysis on the energy consumption per unit of cargo turnover of the inland river and coastal vessels. In 2017, the Ministry of Ecology and Environment organized the Second National Pollution Source Census, which included air pollutant emissions from inland and coastal vessels into the scope of the census. fuel oil sulfur content information, back-calculated to 2017 China's coastal and inland river ship fuel consumption.

On the one hand, the total amount of ship fuel consumption data obtained from the census is relatively accurate and complete; on the other hand, the "bottom-up" method of statistics can avoid the complete absence of fuel supply from abnormal ship fuel channels, and can be used to determine the amount of ship fuel consumption in 2008 and 2017 with certainty.

In addition, the Ministry of Transport has long monitored the energy consumption per unit of cargo turnover of some shipping enterprises with standardized management and published the energy consumption per unit of cargo turnover of ships in the annual "Statistical Bulletin of Transport Industry Development" since 2011. Due to their standardized management and larger scale, the energy consumption per unit cargo turnover of these enterprises' ships should be much lower than the national average energy consumption per unit cargo turnover of ships, which can be used to confirm the feasibility of the annual energy consumption per unit cargo turnover of ships analysis from 2008 to 2017.

3. Conclusion

In the case of air and pipeline transportation with the high cost and policy restrictions, railroad and highway transportation with high energy consumption and pollution, which are not conducive

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to the promotion of "carbon peak" and "carbon neutral" national policies; water transportation with high capacity, low energy consumption, and low pollution, which not only saves energy but also reduces emissions based on economic benefits. It can also reduce emissions based on economic benefits, thus slowing down the pace of global warming, and is the only choice for "green transportation".

As a major component of the transportation construction system, waterway transportation, in the context of a low-carbon economy, requires the establishment of a green waterway transportation development system to form a comprehensive and complete long-term development mechanism. Carbon accounting can directly quantify the carbon emission data, and by analyzing the data of carbon emission in each link, we can find out the potential emission reduction links and ways, which is crucial to the realization of the carbon neutral target, the operation of carbon trading market and the establishment of green waterway transportation development system. Combining the actual situation of the domestic water transport industry and international policy requirements, this paper analyzes the key issues of carbon emission accounting for Chinese water transport enterprises in terms of accounting boundaries and accounting methods and proposes accounting recommendations. In addition to the possibility of determining the accounting boundary of international navigation attributed to China's water transport carbon emissions by international rules, and using census and monitoring information to analyze and calibrate the accounting results of China's domestic water transport carbon emissions, the government is also requested to accelerate the popularization of the concept of low-carbon water transport, cultivate the "low-carbon concept" among operators of ships, ports, and terminals, and prompt them to use low-carbon products, and achieve low carbon in the production and operation process. It also takes a series of measures to promote the construction of water transport infrastructure, promote the application of energy-saving and low-carbon equipment and technologies as well as accelerate the construction of ecological compensation mechanisms in the watershed.

With its unique advantages, waterway transportation is gradually becoming a favorite in the context of the low-carbon economy. I believe that, with the support of the government, waterway transportation will gradually become our main source of power to achieve a low-carbon economy.

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