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Water for Electricity - "Green Shipping" Perspective on the Use of Shore Power in the Port of Jiangxi Economic Zone Low Carbon Effects Study

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Abstract:
Currently, with the increasing awareness of environmental protection, the shipping industry is also facing the challenge of reducing carbon emissions. As an important shipping region, the Jiangxi Economic Belt plays a crucial role in achieving a low-carbon shipping industry Operational objectives are of great significance. This article explores the low-carbon effect brought by the use of shore power at ports in the Jiangxi Economic Belt from the perspective of green shipping. Through the river
The study on the use of shore power at ports along the Ganjiang River in the Western Economic Belt analyzes the specific manifestations of its low-carbon benefits, including reducing greenhouse gas emissions and lowering In terms of low energy consumption and improving air quality, the economic impact of using shore power technology at ports on the Jiangxi Economic Belt was explored. The importance of continuously promoting low-carbon benefits and further researching and promoting this technology was emphasized

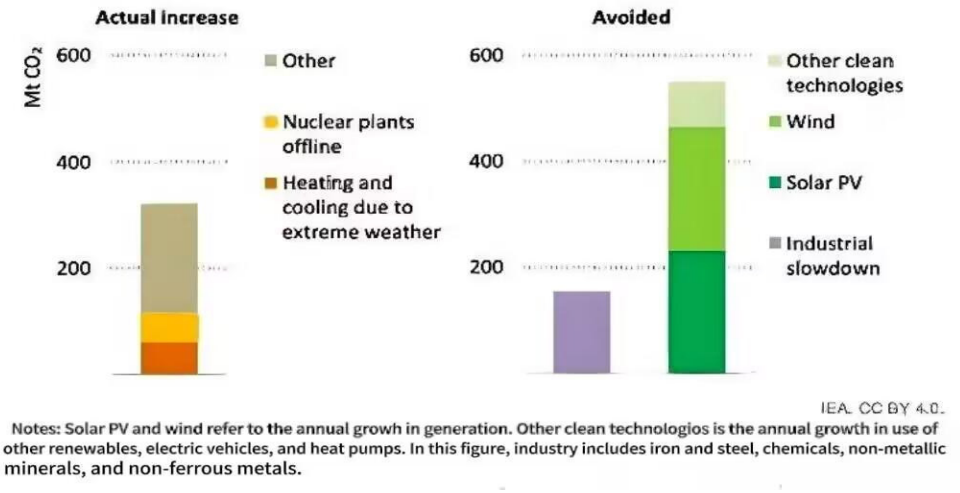
Keywords:
shore power, green port, low-carbon economy, carbon reducti

1 Introduction

On March 2, 2023 Paris time, the International Energy Agency (IEA) released the CO2 Emissions in 2022 report, which provides a complete picture of energy-related greenhouse gas emissions in 2022. The report states that global energy-related CO2 emissions in 2022 will reach a new record high of more than 36.8 billion tons, an increase of 321 million tons, or 0.9%, over the previous year. Global energy-related carbon dioxide emissions in 2022 increased by 0.9% to a new high of 36.8 billion tons, up 321 million tons from the previous year. After two years of unusual volatility in energy use and emissions, last year's growth rate was well below the rebound rate of over 6% in 2021. Energy combustion emissions increased by 423 million tons, while industrial process emissions decreased by 102 million tons. Meanwhile, the report points to changes in global CO2 emissions by driver in 2021-2022, as shown in Table 1.

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Table 1 Changes in global CO2 emissions by driver, 2021-2022 (Image source: CO2 Emissions in 2022)



At the same time, the Jiangxi Economic Zone is relatively backward in the development of water transportation, and the introduction of technologies for the use of shore power is conducive to improving the green water transportation capacity of the ports in the Jiangxi Economic Zone, reducing the negative impacts of ships on the local environment, which is of great significance for the protection of the environment and public health, and helping to meet the challenges of global climate change. For local shipping companies, the use of shore power in ports can reduce fuel costs and maintenance expenses, improve operational efficiency and economic benefits, promote the green transformation of the shipping industry, and enhance the sustainability and competitiveness of the industry. This will not only benefit the environmental image of the Jiangxi economic zone, but also promote the rapid development of the local shipping industry. In addition more broadly, the low carbon technology of onshore power is of great significance to the advancement of green and sustainable development of the global shipping industry.

1.2 Research content and research ideas

1.2.1 Content of the study

Jiangxi economic zone as a rapid economic development along the river area, the low carbon effect of its use of shore power by the port that has been the focus of research attention. The research content of this paper mainly centers on the following aspects:

(1) Reduction of carbon emissions from ships: The study explores the impact of using shore power when berthing on carbon emissions from ships. Through the use of shore power, ships can turn off their engines when berthing, reducing fuel consumption and greenhouse gas emissions, thus reducing carbon emissions.

(2) Air quality improvement: The study focuses on the impact of the use of shore power on air quality in port areas. The use of shore power can reduce air pollutants emitted by ships, improve air quality in port areas and reduce the impact of air pollution on human health.

(3) Water environment protection: Research is being conducted to explore the impact of the use of shore power on the water environment. The use of shore power when ships call at port can reduce the discharge of

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wastewater produced by ships during berthing, reduce the risk of water pollution and protect the health and safety of the water environment.

(4) Low-carbon modeling: Through the support of realistic data, a variety of low-carbon models are utilized for technical research to calculate the reduction of pollutant gas emissions from the use of shore power in the ports of the Jiangxi Economic Zone.

(5) Assessment of economic benefits: The study includes a cost-benefit analysis of shore power facilities and an assessment of the economic viability of shore power. The assessment of economic benefits will provide economic support for the promotion of green shipping and sustainable development.

1.3 Innovations and shortcomings

1.3.1 Points of research innovation

The innovation of this paper is:

Firstly, under the current background of carbon emission reduction, the low-carbon behavior and value impacts of shore power use in ports in the Jiangxi economic zone are discussed in depth. Unlike previous studies that combined the use of shore power with low-carbon behaviors alone, this paper studies from the perspective of green shipping and combines it with case studies to investigate the mechanism of the low-carbon behaviors of using shore power in ports in the economic zone on the low-carbon effect and environmental effect.

Second, a typical port is selected for case study. At present, most of the domestic and international studies on the low-carbon behavior of shore power are based on global or big data, and the relationship between shore power use and low-carbon behavior is examined through data testing methods, and most of them are very general, with some differences only in the selection of metrics and mediating variables, and few specific empirical analyses of the low-carbon behavior of the ports in specific regions. This paper chooses to combine data argumentation with typical cases. By combining abstract data with typical cases, the argumentation process is more vivid and persuasive.

1.3.2 Shortcomings

During the course of the study, some data were estimated due to the difficulty of data sources and standards. These estimates are subject to uncertainties that may affect the results of the study to some extent and require more specific data to support and corroborate them.

2 Theories related to shore power systems

2.1 Basic concepts of shore power for harbor ships

Port ship shore power technology refers to a new technology that uses port power supply system instead of ship auxiliary diesel generator to generate electricity for ships during berthing operation in port, which can greatly reduce pollutant emissions during ship berthing, improve the air environment near the port area, and

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provide a better working and living environment for the residents and staff near the port area.

The ship-to-shore power system consists mainly of a shore power supply system, a ship-to-shore connection system and a shipboard power receiving system. Electricity is supplied from the local power grid and then converted to a frequency and voltage suitable for the ship by a voltage converter. The ship-to-shore connection system consists of cables connecting the shore power interface to the ship's power interface. The shipboard power receives the power transmitted by the connection system and uses it to supply the ship's facilities. When shore power replaces auxiliary diesel engines to meet the power requirements of berthing ships at berth, emissions from harbor ships can be significantly reduced. During ship berthing operations, electricity is supplied by fuel consumed by the ship's auxiliary engines, generating pollutants and noise. The use of shore power in ports can effectively reduce pollutant emissions from ships.

Port shore power is a new type of electric energy alternative technology that can realize energy saving and emission reduction and promote green port construction, and has great development prospects. It can not only bring energy saving, emission reduction and cost saving to ports, but more importantly, it can greatly improve the energy utilization efficiency of ports, make ports more energy-saving and environmentally friendly, and provide a strong support for the construction of green ports and the electrification of port transportation. Port shore power can reduce carbon emissions when ships berth in ports, reduce air pollution in ports and their surrounding areas, support the sustainable development of the shipping industry, and provide a strong guarantee for the realization of the dual-carbon goal.

2.2 Power supply mode of port shore power

Shore power facility refers to the whole of the equipment and devices that provide electric power to the ships docked at the pier by the shore-side power system, which mainly includes switchgear, shore power supply, connecting device, cable management device, etc., as shown in Figure 1. At the same time there are two main types of power supply for harbor shore power: low voltage on board and high voltage on board.

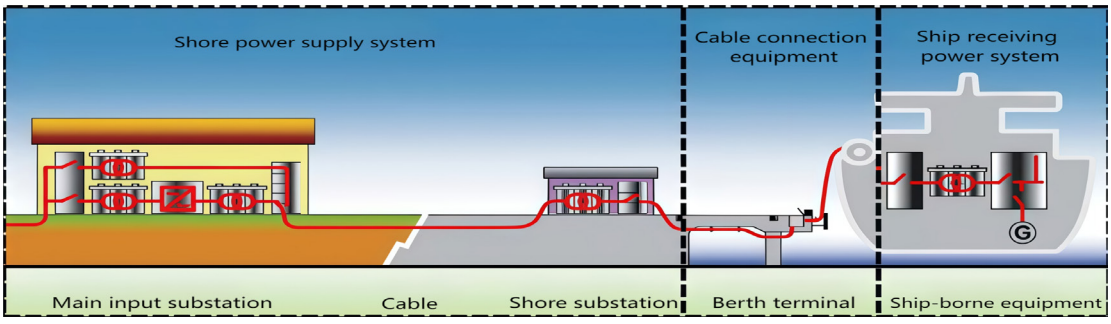


Fig. 1 Schematic diagram of the onshore power supply system (image source: online source)

(1) Low pressure on board

This way is to convert the 10KV/50HZ high-voltage power supply of the terminal grid into 450/400V, 60HZ/50HZ low-voltage power supply through the transformer frequency converter device, which is directly connected to the ship's powered equipment. The scope of application of this power supply method is mainly small ports and terminals. Such as Figure 2.

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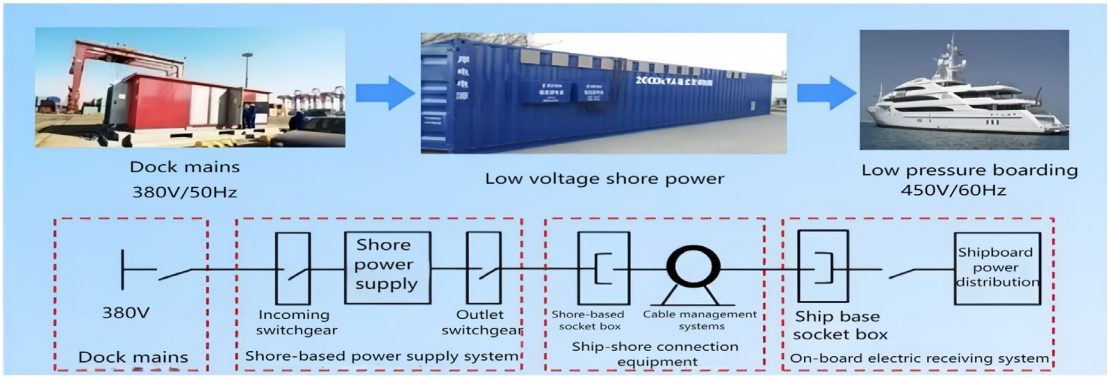


Figure 2 Schematic diagram of low-voltage shore power (image source: online source)

(2) High pressure on board

In this way, the 10KV/50HZ high-voltage power supply of the terminal grid is converted into 6.6/6KV, 60HZ/50HZ high-voltage power supply through the transformer frequency converter device, which is connected to the on-board power supply system for the use of the equipment on board. The scope of application of this power supply method is mainly coastal large port terminals and coastal and riverine medium-sized port terminals. Such as Figure 3.

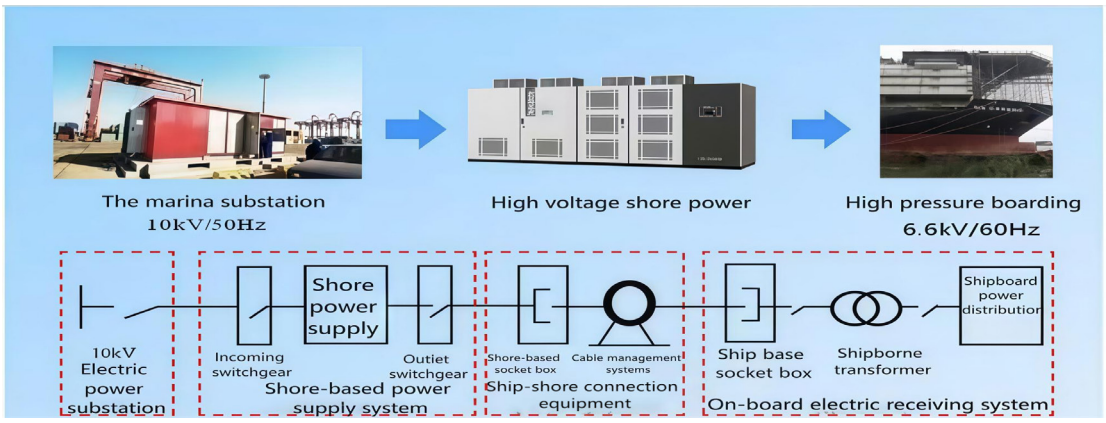


Figure 3 Schematic diagram of high voltage shore power (image source: online source)

2.3 Basic characteristics of port shore power

Ship shore power system uses special equipment to make the ship get electricity for lighting, communication, etc., replacing the previous oil burning power generation system used by ships anchored in ports, avoiding the harmful gas emission produced by burning oil, reducing the water or air pollution brought about by the ships anchored in ports, and effectively changing the environment around the waters. Port shore power has the following characteristics:

(1) Low pollution

Shore power systems can effectively reduce all kinds of pollutants and noise generated when ships use auxiliary fuel generators to generate electricity. For example, the Port of Gothenburg has reduced pollutant

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emissions in the harbor by 94-97% through the use of shore power equipment. At the same time, compared with traditional diesel power generation, shore power systems do not produce exhaust emissions, reducing pollution to the atmosphere and the harbor.

(2) High efficiency

Shore power is typically cheaper compared to oil-fired generation, and using shore power can reduce fuel costs by a significant amount.

(3) High efficiency

Shore power systems use modern grid technology and power electronic conversion technology, and the efficiency of shore power systems is usually higher, allowing for better utilization of energy. At the same time, the use of shore power on ships allows the crew to stop focusing on the maintenance and management of the ship's power generation equipment, which can improve the crew's work efficiency.

(4) Stable

Shore power systems are usually powered by a stable grid that can provide continuous, steady power.

3 Carbon Emission Reduction Effect of Shore Power Use in Jiangxi Economic Zone

3.1 Utilization of shoreline power in the Jiangxi economic zone

3.1.1 Construction of port shore power facilities and use of shore power in the Jiangxi economic zone

Jiangxi Province has achieved remarkable results in the transformation of the receiving facilities of the shore power system for transportation vessels. By the end of 2020, a number of shore power facilities have been built in Jiangxi's economic belt, including port shore power, terminal shore power, etc.. Among them, port shore power facilities are mainly located in Nanchang, Jiujiang and Ganzhou, and terminal shore power facilities are mainly located in Jiujiang and Ganzhou.

In 2021, Jiangxi Province completed the task of transforming and installing the shore power system receiving facilities of 389 transportation vessels. And in 2022, Jiangxi Province is to further advance the work, fully completed the province's 125 berths shore power facilities to enhance the transformation, as well as 265 transport ships shore power system receiving facilities transformation and installation, half a year ahead of schedule to complete the Yangtze River Economic Belt in the eleven provinces and cities in the annual transformation task.

As of the end of November 2021, the cumulative number of times shore power facilities were used in Jiangxi Province showed significant growth. Specific data shows that the number of usage reached 24,600 vessels, an increase of about 124.06% year-on-year. Meanwhile, the cumulative hours of shore power usage reached 295,160,000 hours, a year-on-year increase of about 180.48%. In addition, the cumulative amount of

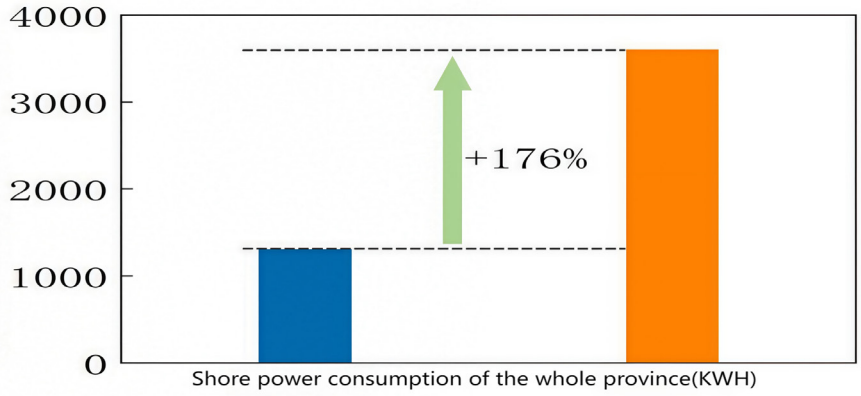
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electricity used for shore power reached 281,250,200 kWh, an increase of about 159.39% year-on-year.

In 2022, our province included 265 ships in the project plan for the transformation of shore power system receiving facilities for transport ships in the Yangtze River Economic Belt, and applied for a total of 14.235 million yuan in subsidies.By the end of June 2022, the annual transformation task had been fully completed, and the subsidies had been basically issued in place. Third, promoting the construction and transformation of shore power facilities at terminals. Actively guide the local port management department i department to promote the construction and transformation of terminal shore power facilities within the jurisdiction, 2022 annual 123 berths shore power facilities installation, transformation tasks have been completed at the end of August of that year. As of the end of December, the province's use of shore power ship times totaled 30,226, the use of shore power time totaled 316,896 hours, the use of shore power power power totaled 359,943 kWh.

Jiangxi ports and ships shore power utilization rate increased significantly. "Fourteenth Five-Year" cumulative completion of 146 bulk, general cargo, container and other berths (including all new, rebuilt, expanded berths) of the port shore power facilities construction tasks, to achieve full coverage of port terminals shore power facilities, more than 1,000 tons of berths have basically have the ability to supply shore power. Comprehensively complete the transformation of inland river container ships, dry bulk carriers and multi-purpose ships of 1,200 gross tons and above, as well as sea-into-river ships. 2022 the province's cumulative number of times the shore power facilities were used a total of 30,200 times, and the cumulative use of shore power electricity amounted to 359,900 kilowatt-hours, an increase of 176% compared with that of 2020. As shown in Table 2.

Table 2 Comparison of the province's shore power usage in Jiangxi in 2020 and 2022 (Image source: Jiangxi Transportation Bureau)



3.1.2 Pollution and carbon emissions from shipping in the Jiangxi economic zone

The pollution situation of shipping in the Jiangxi Economic Zone is affected by a variety of factors, mainly including ship exhaust emissions, ballast water emissions, oily sewage emissions and ship garbage. Among them, ship exhaust emission is one of the main sources of shipping pollution, and its main pollutants include sulfur dioxide, nitrogen oxides, particulate matter and so on. According to statistics, ship exhaust emissions in the Jiangxi economic zone account for more than 50 per cent of total emissions.

In order to realize the green development of shipping, jiangxi province has taken a series of initiatives.

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2020, jiangxi province continues to promote the closed-loop management of water pollutants on board ships and ports, the year the rate of domestic garbage and sewage transfer and disposal rate of more than 90%. 2022, jiangxi province in the inland waterway provinces took the lead in launching the water pollutants on board ships, "zero discharge" work, and has achieved remarkable results. In 2022, Jiangxi Province took the lead in launching the work of "zero discharge" of water pollutants from ships among inland river provinces and achieved remarkable results.

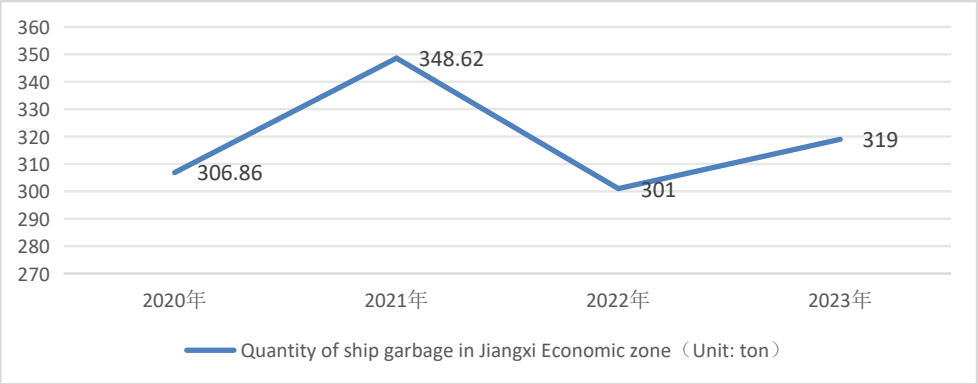
The data show that as of the end of November 2021, the annual amount of ship garbage received in Jiangxi Province was 348.62 tons, a year-on-year increase of 13.92%; the annual amount of domestic sewage received was 29,219.82 tons, a year-on-year increase of about 882.72%; and the annual amount of oily sewage received was 705.06 tons, a year-on-year increase of about 1,581.17%.

However, as of the end of 2022, the annual amount of ship garbage received was 301 tons, a year-on-year decrease of about 13.66%; the amount of domestic sewage received was 53,365 tons, a year-on-year increase of about 82.63%; and the amount of oily wastewater received was a total of 204 tons, a year-on-year decrease of about 71.05%. Meanwhile, the disposal rate of pollutants from all types of ships in Jiangxi Province exceeded 98% in 2023.

These data indicate that the amount of ship garbage received and oily sewage received in Jiangxi's economic zone is on an upward trend from 2019 to 2020, and on a downward trend from 2020 to 2021. This change in trend is due to the fact that 2021 is the starting year for the reconstruction of shore power system receiving facilities for transport vessels in Jiangxi Province, and as of November 30, 2021, the province completed the reconstruction of shore power system receiving facilities for vessels in that year ahead of schedule.

This shows that strengthening the application of shore power technology in port cities can effectively solve the problem of pollution during ship berthing and have a positive effect on improving the port environment. Promoting shore power technology can reduce exhaust gas and noise pollution during ship berthing, improve energy utilization and reduce the impact on the environment around the port. This is not only conducive to ecological protection, but also helps to enhance the port's sustainable development capability. Specific data are shown in Table 3, Table 4 and Table 5.

Table 3 Amount of shipboard garbage in the Jiangxi Economic Zone from 2020 to 2023 (Image source: collected by the team)



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Table 4 Volume of oily wastewater in the Jiangxi economic zone from 2020 to 2022 (Image source: collected and organized by the team)

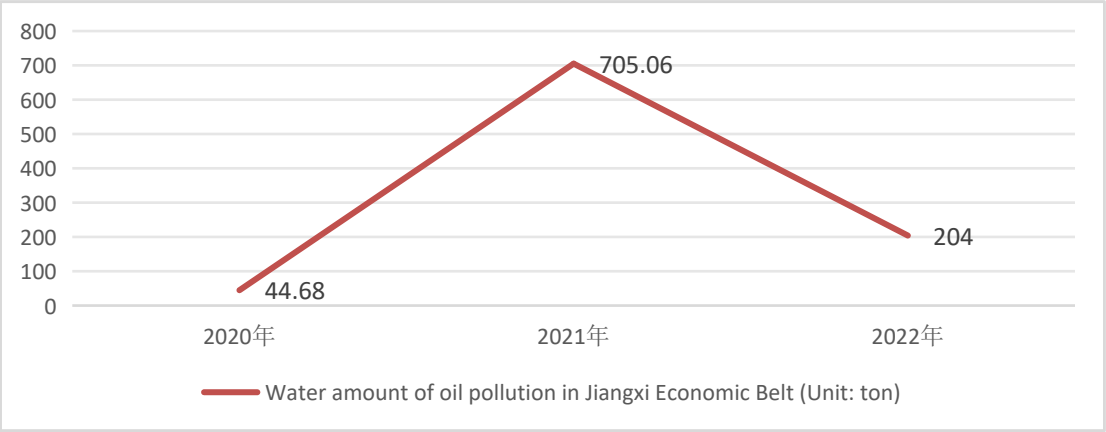
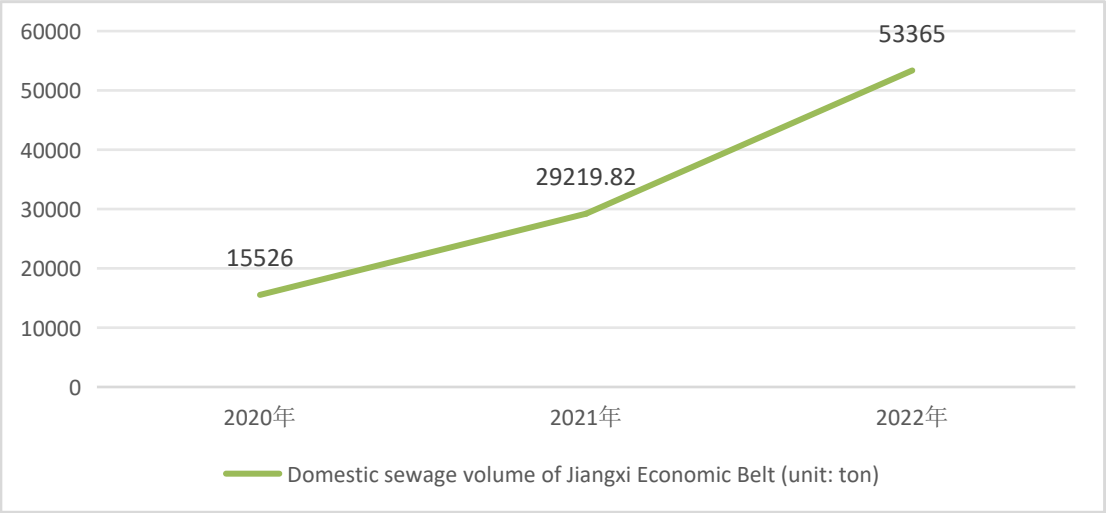


Table 5 Volume of domestic wastewater contained in the economic zone of Jiangxi from 2020 to 2022 (image source: collected by the team)



In terms of carbon emissions, compared with 2005, carbon dioxide emissions and energy consumption per unit of transportation turnover of operating ships decreased by 16% and 15% respectively. Compared with 2015, the energy consumption and carbon dioxide emission intensity per unit of transportation turnover of operating ships decreased by 10% and 12.5% respectively, and the comprehensive energy consumption and carbon dioxide emission per unit of throughput of port production decreased by 2% and 2% respectively.

It is worth mentioning that the generating units of the navigation and power hubs belonging to the provincial port groups play an important role in reducing carbon dioxide emissions. The operation of these generating units helps to promote economic and social development in the direction of green, low-carbon and sustainable development. As of August 2023, the cumulative multi-year power generation of the Group's navigation power segment reached 7.586 billion kWh, saving about 2.4 million tons of standard coal and reducing carbon dioxide emissions by 7.47 million tons compared with thermal power.

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3.2 Carbon reduction effects of emission modeling based on fuel consumption

3.2.1 Introduction to emission modeling based on fuel consumption

Fuel consumption-based emission modeling is a method of estimating pollutant emissions by counting or monitoring total fuel consumption. The following are the basic steps of the model:

(1) Collection of fuel consumption data: This step is usually carried out by obtaining, through various means, data on the total amount of fuel consumed in a given country or region, with a commonly used indicator being the volume of a particular fuel (e.g., gasoline, diesel, natural gas, etc.) sold or used.

(2) Determination of emission coefficients: For each fuel, there are corresponding emission coefficients. These coefficients represent the amount of pollutants emitted per unit of fuel consumed, and they can be determined by experimental measurements, data analysis or reference to relevant literature.

(3) Calculation of emissions: Finally, by multiplying the total fuel consumption with the corresponding emission factors, it is possible to calculate the pollutant emissions for the country or region.

This type of modeling has the advantage of simplicity of operation and relatively easy access to data. However, it also has some limitations, such as the inability to specify the specific contribution of different types of fuel use activities (e.g., transportation, industrial production, home heating, etc.) to emissions.

3.2.2 Selection of indicators and data analysis

The formula for modeling emissions based on fuel consumption is:

(1) $Pp= \sum_{i=1}^{n} Epi \times (F \times Ai)$

The formula expands to:

(2) Nitrogen emissions: $Pp = Ep_1(F \times A_1) + Ep_2(F \times A_2) + (F + A_3)$.

(3) Sulfur emissions: $Pp = Ep_1(F \times A_1) + Ep_2(F \times A_2)$

① Total amount of nitrogen and sulfur emissions (Pp): The total amount of nitrogen and sulfur emissions has a significant impact on the emission of pollutants. Nitrogen oxides (NO_2) and sulfur oxides (SO_2) are among the major contributors to air pollution. These pollutants react with other compounds to form harmful substances such as ozone, fine particulate matter (PM2.5) and acid rain. Nitrogen and sulfur emissions from combustion vary between different types of fuels. For example, coal typically produces more sulfur emissions than oil or natural gas, while certain fuels (such as diesel) may produce higher levels of nitrogen oxides.

② Emission factors (Ep,i): For different types of emissions, different turbine types (for nitrogen emissions) or fuel types (for sulphur emissions), there exist corresponding emission factors. The emission factor of a fuel refers to the proportionality between the release of various pollutants during fuel combustion and fuel consumption. The size of the emission factor plays a key role in the calculation and prediction of pollutant emissions. A higher emission factor implies a corresponding increase in pollutant emissions for the same fuel

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consumption.

③ Total amount of fuel consumed per year (F): The amount of fuel consumed per year directly affects the amount of pollutants emitted. In general, fuel consumption is directly proportional to pollutant emissions. More fuel use means more chemical reactions and combustion processes, which produce more pollutants.

④ Proportion of all ships with a certain type of turbine or proportion of all ships using a certain type of fuel (Ai): There may be differences in the emissions of pollutants from the combustion of different types of fuel. For example, certain fuels may produce higher emissions of sulphur oxides (SOx) or nitrogen oxides (NOx). Therefore, if a higher proportion of ships use a certain fuel, the overall pollutant emissions may increase accordingly. In addition, there may be differences in energy efficiency and emission control between different types of turbines. Advanced turbine technologies typically have better fuel efficiency and lower pollutant emission levels. If a higher proportion of ships are equipped with advanced turbines, overall emissions may be lower.

⑤ i: In the calculation of nitrogen emissions, i is equal to 3 (where 1 represents slow turbines, 2 represents medium-speed turbines, and 3 represents other turbines); and in the calculation of sulphur emissions, i is equal to 2 (where 1 represents precipitating fuels and 2 represents other fuels).

In 2023, a total of 7,691 ships will operate in Gan River locks. According to the fuel quantity of normal ships, a ship burns about 31,025 tons per year, and the total fuel consumption of Gan River ships in 2023 will be about 2,386,13275 tons.

Calculating the number of liters of heavy fuel oil consumed: Convert the tons of heavy diesel oil consumed by the ship to liters. Since 1 ton is equal to 1,000 liters, 2,386,13275 tons is equal to 2,386,13275,000 liters.

Calculation of CO_2 emissions: Based on the heavy oil emission factor of 2.991kgCO_2/L, multiply the number of liters of heavy oil consumed by the emission factor to obtain the CO_2 emissions. That is, 238613275000 liters × 2.991kgCO_2/L = 693303427750kgCO_2.

It should be noted that the above calculations are simple analyses based on the given heavy fuel oil emission factors and fuel consumption data. In practice, it may be necessary to consider other factors, such as the quality of the fuel, combustion efficiency, operating conditions of the ship, etc., in order to more accurately assess the CO_2 emissions from the ship. In addition, such an analysis usually needs to be conducted in conjunction with specialized ship energy efficiency assessment methods and standards.

3.3 Analysis of model results

Heavy fuel oil emissions from ships cause serious environmental pollution. Carbon dioxide contained in heavy fuel oil is the most important greenhouse gas

one of the most important impacts on global climate change. This makes heavy fuel oil emissions from ships a key factor in environmental issues.

Calculated by the model, the CO2 emissions from shipping in Jiangxi province in 2022 will be as high as 483,480.195 tons. This alarming figure highlights the huge consumption of energy and the significant environmental impact of the ship transportation industry. Such a huge consumption of heavy fuel oil and CO2 emission not only poses a challenge to energy supply, but also puts a heavy pressure on the environment.

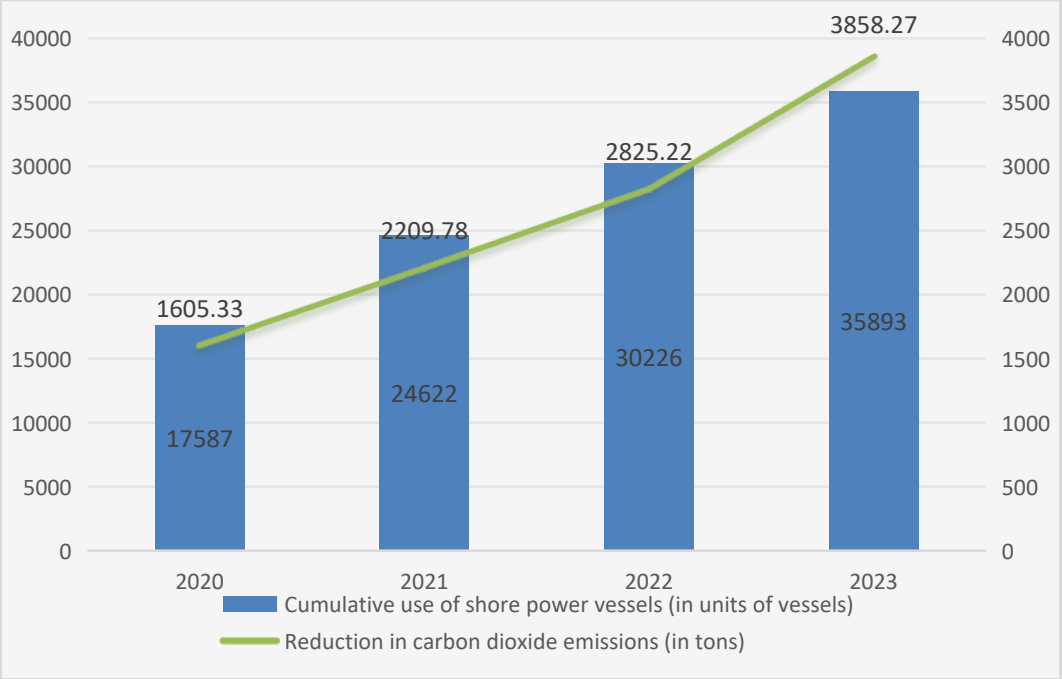
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It is known that saving 1 kWh of electricity can reduce the emission of about 7850 grams of carbon dioxide into the atmosphere. 2020, Jiangxi province accumulated the use of shore power ships 17,000 times, the cumulative use of shore power about 2045,000 kWh, 21 years in Jiangxi province accumulated the use of shore power 24622 times, the cumulative use of shore power 2815,000 kWh. 2022 Jiangxi province accumulated the cumulative number of times the use of shore power facilities totaled 30,200 times, the cumulative use of shore power 35.99 million kWh. In 2022, the cumulative use of shore power facilities in Jiangxi province totaled 30,200 vessels and the cumulative use of shore power amounted to 359,900 kWh. Therefore, we can get that in 22 years, Jiangxi province reduced the emission of 359900 kWh×7.85kg CO2/kWh=2825.215 tons of carbon dioxide into the atmosphere because of the use of shore power.23 In 23 years, the accumulated number of ships in Jiangxi province reached 35893 times, and the cumulative use of shore power was about 491,500 kWh, and the reduction of emission of carbon dioxide was about 3858.27 tons according to the formula. The specific results are shown in Table 6 and Table 7.

Table 6 Shore power utilization in Jiangxi Province, 2020-2023

particular year	Cumulative use of shore power vessels (in units of vessels)	Cumulative use of shore power (in 10,000 kWh)	Carbon dioxide emission reductions (in tons)
2020	17587	20.45	1605.33
2021	24622	28.15	2209.78
2022	30226	35.99	2825.22
2023	35893	49.15	3858.27

Table 7 Vessels using shore power and carbon emission reduction in Jiangxi Province, 2020-2023



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4 Conclusions of the study

In the context of achieving carbon peak and carbon neutrality goals, this article analyzes the low-carbon benefits of using shore power in the Jiangxi economic belt and the environmental and economic impacts it brings. Taking the Ganjiang River navigation lock as the research object, by analyzing the emission model of ship fuel consumption in the Ganjiang River ports in 2023, it is concluded that the carbon emission reduction effect of using shore power can optimize the industrial chain of ship transportation, which is conducive to promoting the construction of green port areas and achieving the dual carbon goals in port regions. At the same time, it is also beneficial to the strategic position of the Jiangxi economic belt within the Yangtze River economic belt.

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