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Research on the Intelligent Transformation of Green Clean Energy Detection and Certification in Shanghai Port from the Perspective of Low-Carbon Empowerment

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Abstract: Under the continuous advancement of the "dual carbon" goal, ports, as centers for international cargo trade, have undergone a low-carbon transformation, which is an important part of China's green and sustainable opening-up. Based on this, this paper explores the intelligent transformation of green clean energy inspection and testing in the Shanghai Port Area, analyzes the current development status and latest intelligent policy orientations of green clean energy detection and certification in the Shanghai Port Area, discusses the new requirements for port inspection business brought about by low-carbon development, examines existing problems from the perspectives of processes and technologies, and proposes optimization countermeasures. The aim is to propose optimization strategies from two levels: optimizing technical means and improving mechanisms. The research results can provide certain references and inspirations for the transformation of green clean energy detection in the Shanghai Port Area, strengthening intelligent construction, and reducing carbon emissions.

Keywords: Low-carbon technology; Shanghai Port Area; Green clean energy; Inspection and testing; Intelligent transformation

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1. Introduction

The Shanghai Port Area, as one of the largest ports in China, is expected to handle over 120 million tons of clean energy goods in 2025, accounting for 23% of the national port throughput of such goods. The traditional manual verification, offline sampling for testing and certification methods cannot meet the increasing business volume demands and have problems such as high carbon emission intensity and low verification efficiency [1]. At the same time, the rapid iteration of intelligent technologies such as the Internet of Things, artificial intelligence, and big data provides technical feasibility for the low-carbon and digital upgrade of port

inspection, quarantine and certification business. In this context, this paper explores the intelligent development path of green clean energy inspection and testing in the Shanghai Port Area from the perspective of low-carbon empowerment. By applying intelligent technologies to the carbon emission reduction work throughout the inspection and testing process, it helps the Shanghai Port Area achieve the goal of low-carbon operation, improve the inspection and customs clearance efficiency of clean energy goods, and further enhance the competitiveness of the Shanghai Port Area as a trade hub.

2. From the perspective of low-carbon empowerment, the value of the intelligent transformation of clean energy detection and certification in the Shanghai Port Area

2.1. Current development status and policy background of green clean energy detection and certification in the Shanghai Port Area

The Shanghai Port is a core hub for global green clean energy imports and exports. By 2025, the total volume of imports and exports of green energy products such as green methanol, liquefied natural gas, biodiesel, green ammonia, and sustainable aviation fuel (SAF) will continue to increase, and a complete detection and identification system covering inspection, traceability, and traceability has been established. Currently, the green energy inspection business in this port is classified by product type: liquid green energy (such as green methanol, biodiesel, liquefied natural gas) accounts for more than half; gaseous green energy (such as green hydrogen, compressed biogas) accounts for nearly one-third; solid biomass fuels have also seen significant growth. There are obvious differences in detection indicators and operational procedures among different categories. At the policy level, the "14th Five-Year Plan for Green Ports" of the country has set a target: "By 2027, the intelligent coverage rate of green energy detection in key ports will reach 50%". The Lingang New Area of the Shanghai Free Trade Zone has also introduced specific policies to support the intelligent technological upgrading of green energy inspection institutions, providing policy support for the intelligent transformation of port inspection and certification. However, the intelligent application of green energy detection in the Shanghai Port Area is still in the pilot stage. Currently, only some green methanol detection points have deployed online sensing equipment. The overall intelligent coverage rate is insufficient, and there is a significant gap between it and the policy requirements and business growth needs [2].

2.2. Intelligence is the core requirement for the green clean energy detection and certification work in ports.

From the perspective of low-carbon empowerment, there are three core requirements for the intelligent transformation of green and clean energy testing and certification in Shanghai Port Area. First, the testing process itself should be low-carbon. By replacing the manual operation and offline circulation of high energy consumption with intelligent technology, carbon emissions in the testing process can be reduced. Secondly, the detection content should adapt to the low-carbon attribute, where the intelligent detection system should cover the verification of green energy carbon footprint, the certification of low-carbon attributes, etc., and these contents should comply with the special regulatory requirements of green energy trade; Finally, the detection efficiency should achieve low-carbon synergy. By improving the detection and release efficiency through intelligent means, indirect carbon emissions such as cargo detention and vessel berthing can be reduced, achieving low-carbon synergy between the detection process and the overall operation of the port. From the perspective of value logic, intelligent transformation is an inevitable choice for the green energy detection

system of Shanghai Port Area to adapt to business growth. On the one hand, intelligent detection can shorten the average detection time of each batch of green energy, which is conducive to the average annual growth of green energy throughput in Shanghai Port Area in the next three years. On the other hand, intelligent detection can accurately verify the low-carbon attributes of green energy, preventing "fake green electricity" and "fake low-carbon fuels" from flowing into the market through the port, providing technical support for the standardized development of China's green energy trade, and at the same time providing value-added services such as carbon footprint tracking and low-carbon qualification certification for enterprises, thereby enhancing the service competitiveness of the Shanghai Port Area in global green energy trade [3].

3. Problems in the intelligent process of clean energy detection and certification in the Shanghai Port area

3.1. The current energy efficiency of the detection and certification process is insufficient

The traditional detection process in the Shanghai Port Area has a high carbon emission intensity, which is much higher than that of ports in the European Union and Singapore. In the specific detection process, the vehicle scheduling and personnel arrangement of sample transportation are still unreasonable. A large number of inspectors need to travel between the port and the laboratory to transport samples, and the average transportation distance for a single sample is relatively long. The standby energy consumption of the detection equipment is also high, and some equipment models are outdated, with low energy efficiency. Some relevant documents of the inspection institutions require multiple departments to sign and stamp to ensure their validity, resulting in unnecessary consumption every year. This leads to a high indirect carbon emission level and obvious resource waste problems. The Shanghai Port Area needs to conduct various types of inspections. The imported clean energy products are diverse (including high-pressure gas hydrogen, photovoltaic components, etc.), and the inspection standards for different categories have not been unified. The documents of Shanghai Port Area, energy and environmental protection departments are not comprehensive enough for different types of low-carbon inspection requirements, and lack unified operating guidelines, where some clean energy inspections do not include carbon footprint verification procedures, some do not include leakage emission detection projects, and some latest technologies have not yet included raw material low-carbon attribute certification requirements. The dispersion and non-uniformity of the standards require inspection institutions to formulate differentiated plans for different categories, which not only leads to duplicate inspection work in the Shanghai Port Area but also prolongs the cycle for trade enterprises to obtain low-carbon attribute certifications for clean energy products, thereby resulting in additional indirect carbon emissions. Currently, the clean energy inspection projects in the Shanghai Port Area still mainly rely on manual operations (including sample collection, inspection, report issuance and review, etc.). The inspection cycle for some special categories is about one week, which not only prolongs the detention time of goods but also increases costs such as refrigeration and pressure storage. To ensure the stability of the supply chain, enterprises usually choose expedited inspections and pay additional fees, which indirectly increases their operating costs and carbon emissions. The temporary deployment of extra inspectors in the Shanghai Port Area to shorten customs clearance times has also added to the workload and indirectly led to more carbon emissions. This inefficient process hinders the effective synergy between the low-carbon emission target and the improvement of customs clearance efficiency, and affects the achievement of emission reduction targets [4].

3.2. Insufficient application fields of intelligent technologies

At present, the level of digitization and intelligence of testing equipment is still low, and technical transformation is urgently needed. Ten years ago, the Shanghai Port region had widely carried out information system construction, resulting in most equipment having a service life exceeding five years. However, due to the relatively lagging intelligent construction, currently most equipment lacks data interfaces and intelligent sensing modules, and cannot automatically collect and transmit environmental and inspected product information. Different detection processes use different brand and model equipment, and the communication protocols are not unified. Some imported equipment has underlying technical parameters that are incompatible with domestic equipment, making the intelligent transformation of the equipment layer difficult and the overall transformation cost high (especially the overall transformation of imported equipment in the port), and if testing institutions only rely on market investment to promote intelligent transformation, they will be affected by financial pressure in the short term.

The clean energy inspection data in the Shanghai Port region is scattered among port supervision, ports, manufacturers, etc., and there is no information sharing among institutions. The data format, encoding rules, and storage standards lack uniformity. Data interaction between institutions requires coordination from higher authorities and manual exchange. Ports not only bear corresponding data security risks but also bear coordination costs, and they need to eliminate the concerns of enterprises and regulatory agencies regarding data sharing. At present, the incentive mechanism, responsibility and authority division mechanism of cross-institutional data sharing has not been established. Data providers cannot obtain reasonable returns from sharing but have to bear corresponding responsibilities and risks, which affects the enthusiasm of institutions to share data. At the application technology level, the recognition of intelligent detection results by the industry is still insufficient. For example, the measures taken by the port to use artificial intelligence for automatic assessment to detect clean energy have not been included in the qualification recognition scope of national testing institutions; the reports issued by intelligent detection have not been mutually recognized by some countries and international organizations, and cannot be used as legal basis for enterprise customs clearance and trade settlement. Therefore, the enthusiasm of enterprises to participate in intelligent transformation is generally low, which restricts the promotion and application of the intelligent detection model.

4. The intelligent development strategy for green clean energy detection and certification in Shanghai Port Area

For the development of clean energy itself, low-carbon detection is indispensable. Intelligent processes and the expansion of intelligence are consistent with the goals of clean energy development. The following aspects are discussed.

4.1. Rebuild the intelligent process to improve process efficiency

Shanghai Port Area should comprehensively review the existing detection process and use intelligent equipment for on-site rapid detection, gradually replacing traditional laboratory tests; the intelligent detection results gradually replace the round-trip transportation of samples and repeated on-site verification, thereby reducing carbon emissions in the detection process. Intelligent systems that have been abandoned should be replaced immediately, and the power of the equipment should be automatically adjusted according to the detection task to improve the efficiency of energy use. Gradually eliminate paper documents and circulation, reduce

indirect carbon emissions and resource consumption. Shanghai Port Area should lead and organize multiple participants to jointly formulate unified inspection standards based on different types of clean energy and incorporate them into the daily work processes of Shanghai Port Area and energy bureau inspection institutions to ensure that each clean energy inspection project can be uniformly managed. Inspectors should use the same set of operation procedures for sample testing to meet the specific requirements of low-carbon indicators and develop corresponding intelligent inspection scenarios based on the unified standards to conduct inspections of various clean energy products in the port area, thereby reducing the carbon emission intensity of the entire process. Rapid release of product carbon labeling reports to improve work efficiency, and a combination of standardization and customization to meet the low-carbon inspection requirements of different clean energy categories.

The deployment of additional unmanned inspection modules in the Shanghai Port Area can significantly enhance the customs clearance efficiency of clean energy products through intelligent process optimization. By integrating inspection equipment with advanced sensor technologies, a comprehensive intelligent inspection system can be established to support automated data acquisition, real-time monitoring, and intelligent analytics. This approach enables more effective control of inspection activities, improves operational efficiency, and shortens inspection cycles. Consequently, cargo dwell times are reduced, leading to lower carbon emissions associated with storage and logistics delays. Moreover, reduced warehouse energy consumption and decreased reliance on emergency personnel dispatch contribute to improved energy efficiency and support the development of low-carbon and sustainable port operations.

4.2. Enlarge the applied area of smart technology

The Shanghai Port Area should strengthen policy support for the adoption and application of intelligent technologies. Specific measures may include establishing dedicated funds for intelligent transformation, providing tax incentives and financial subsidies for institutions introducing intelligent inspection equipment, and reducing the financial burden associated with technology investment. In addition, collaboration among local universities, research institutes, and intelligent equipment manufacturers should be encouraged to address key technical challenges in the development and deployment of intelligent inspection systems within the port area.

To meet the diverse inspection requirements of the Shanghai Port Area, intelligent detection equipment from different manufacturers should be standardized and interconnected through unified energy-detection data collection modules. Such integration would reduce data-sharing barriers across different stages of the inspection process and facilitate the expansion of intelligent technology applications. Furthermore, the adoption of standardized intelligent equipment across different inspection institutions should be promoted to establish an equipment-sharing mechanism. For specialized inspection equipment with low utilization rates, a comprehensive assessment should be conducted, followed by the establishment of a centralized sharing platform. This platform would enable the coordinated allocation and circulation of intelligent inspection equipment among multiple institutions, thereby improving resource utilization, reducing redundant investments, enhancing service convenience for enterprises, and maximizing the effectiveness of intelligent inspection applications through unified management and scheduling.

The Shanghai Port Area should also formulate unified clean energy data inspection standards to ensure unobstructed data sharing among different departments and entities. For instance, clearly define the formats,

encoding rules, and interface specifications for data sharing among different institutions, enabling entities to achieve seamless connection when sharing data, enhancing the continuity of data sharing between entities without revealing the original data, and strengthening the consistency of data sharing among entities without causing disputes; through clear operation guidelines, ensure clear ownership of data, reduce disputes caused thereby. The Shanghai Port Area can collaborate with third-party enterprises to deploy data encryption technology and strengthen access control to ensure that each entity can obtain effective security guarantees during data sharing.

The Shanghai Port Area should strengthen international exchanges and mutual recognition, incorporate the intelligent detection model into the qualification recognition scope of more countries, clarify the legal effect of national-level intelligent detection reports by gradually promoting the mutual recognition mechanism for intelligent detection results in the Yangtze River Delta region, expanding cooperation with major trading partners such as the European Union and ASEAN, reducing carbon emissions caused by repeated manual inspections. Through more comprehensive agreements, clearly define the scope of responsibility for errors caused by technical defects, improper operation, and system failures, improve the accuracy of intelligent detection, eliminate the concerns of inspection institutions and enterprises regarding application, and clarify the application of intelligent technologies.

5. Conclusion

Low-carbon itself is the core objective of the development of the clean energy business. This article explores the issue of intelligent green clean energy inspection and testing in the Shanghai Port Area from the perspective of low-carbon empowerment, analyzing the current situation and existing problems and proposing corresponding countermeasures. Currently, the clean energy testing and certification work in the Shanghai Port Area has an urgent need to carry out a low-carbon transformation. The traditional model has deficiencies in energy efficiency loss, category compatibility, customs clearance efficiency, technological renovation, data sharing, and result certification. Intelligence can help solve these problems and improve the overall testing effect. The Shanghai Port Area should specifically plan low-carbon technological transformation, intelligent testing, and unmanned verification modules in different scenarios, and improve supporting mechanisms such as equipment renewal, data sharing, and result mutual recognition. In the future, the Shanghai Port Area will promote the intelligent transformation in the field of clean energy testing and certification, providing more complete institutional guarantees, technical guarantees, and human resource guarantees, coordinating cross-departmental issues, promoting phased implementation of policies, strengthening policy support, and evaluating the long-term benefits of the intelligent transformation, and making timely adjustments.

Disclosure statement

The authors declare no conflict of interest.

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