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Research on the Development of China's Steel Industry and the Current Status of Carbon Emissions

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Abstract— *The paper provides a comprehensive analysis of the current development status of China's steel industry and the carbon emission challenges it faces. The steel sector has gradually evolved towards mechanization, large-scale operations, and specialization due to technological advancements and policy guidance. However, it still encounters issues such as high carbon emissions and low resource utilization efficiency. The article emphasizes the critical roles of policy regulation and technological innovation in facilitating the steel industry's transition to low-carbon development. It proposes future development strategies, including optimizing production structures, enhancing emission reduction technology applications, and promoting the commercialization of carbon neutrality technologies. These measures aim to achieve high-quality and environmentally sustainable development in the steel industry.*

Keywords— *Steel industry,Carbon emissions,Green development.*

I. THE CURRENT DEVELOPMENT STATUS OF CHINA'S STEEL INDUSTRY

A. The Current Status of the Steel Industry Development

With the rising labor costs in China and the expansion of steel processing enterprise scale, mechanization, large-scale operation[1], specialization, and standardization of steel processing equipment have become mainstream trends. Large steel processing and distribution enterprises are equipped with large hydraulic gantry shears, with domestic manufacturing capabilities now reaching up to 800-1250t capacity for such equipment. Several enterprises have introduced specialized equipment for scrap steel processing, including scrap crushing production lines that operate at internationally advanced and domestically leading levels. Conventional steel enterprises are commonly equipped with gantry radiographic testing devices and portable radiographic testing devices. Some enterprises have gradually replaced outdated processing techniques, such as relying on drop hammers for crushing and processing slag steel, by importing more advanced 20t class "stone steel hammers" from overseas[2].

For many years, the steel industry in China has been dominated by small enterprises characterized by dispersed development and disorderly operations. In comparison to mature steel resource recovery and processing systems abroad, there is a significant gap in domestic industrial development levels.

The China Iron and Steel Association, as an industry organization, is further guiding the industry towards scale and industrialization[3], actively promoting the construction of scrap steel processing and distribution base centers and demonstrating base centers for steel processing and distribution.

The new tax refund policy for resource comprehensive utilization products and services, jointly issued by the Ministry of Finance and the State Administration of Taxation, has changed previous financial and tax subsidies that supported the entire industry to subsidies targeting compliant large and medium-sized steel processing enterprises. The major beneficiaries are the 151 compliant scrap steel processing enterprises, and the concentration of market resources and competitiveness towards large and medium-sized steel processing enterprises is becoming an inevitable trend.

B. Carbon Emissions in the Steel Industry

The steel industry faces the challenge of significantly reducing emissions while maintaining competitiveness. It ranks among the largest global contributors to carbon dioxide emissions, with steelmaking alone emitting over 3 billion metric tons of CO2 annually, making it the industrial material with the most significant climate impact. This accounts for approximately 7% to 9% of direct fossil fuel emissions (i.e., greenhouse gases) and 11% of global CO2 emissions. While peak steel consumption in many developed economies may have passed, domestic industries in emerging markets and developing economies continue to grow. Despite efforts to enhance material efficiency through strategies like lightweighting in automobiles or extending building lifespans, steel remains a crucial input in infrastructure, construction, and transportation systems, serving as a key driver in global energy transformation [4].

China, the world's largest consumer and producer of steel, had an apparent per capita steel consumption of 645.8 kilograms in 2022. China accounted for 54 percent of global crude steel production of 1.885 billion tons, producing about 1.018 billion tons. In 2022, the Chinese steel industry consumed about 580 million metric tons of standard coal equivalents, representing 11.6% of China's total energy consumption and contributing to approximately 15% of the nation's CO2 emissions. This accounts for over 60% of global steel industry emissions, positioning it as one of China's highest carbon-emitting manufacturing sectors[5].

Coal and coke comprise 92.0% of China's steel industry energy inputs, significantly higher than the 57.5% share of coal in China's overall energy consumption structure, with electricity consumption accounting for only 6.3%. Renewable electricity sources (such as solar and wind) represent less than

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1% of this consumption [6]. In response, the China Iron and Steel Association released the "Carbon Neutrality Vision and Low Carbon Technology Roadmap for the Steel Industry" in 2022, highlighting steel as a pivotal sector for China's energy consumption and CO2 emissions reduction efforts. Achieving significant reductions in energy consumption and emissions within China's steel industry will have profound implications for both national and global energy consumption and emissions, underscoring the critical role of low-carbon transformation in achieving China's long-term 2060 carbon neutrality goal.

II. THE EXTANT ISSUES OF THE STEEL INDUSTRY WITH CARBON EMISSIONS

A. Insufficient demand affects the healthy development of steel enterprises.

With iron ore prices significantly low, steelmakers find the cost advantage of using iron ore in blast furnaces over scrap steel evident. This trend has led major steel enterprises to universally reduce iron consumption and diminish their enthusiasm for procuring scrap steel. Consequently, the operational scale of steel processing enterprises has contracted, with production capacities unable to be fully utilized, thereby resulting in diminished economic performance. Moreover, the volume of recycled scrap steel processing has notably decreased, dampening the initiative of steel processing enterprises and adversely affecting the healthy development of the scrap steel industry. This scenario reflects persistently high processing costs in the steel sector, rendering it challenging to provide cost-effective steelmaking raw materials. Furthermore, it underscores the difficulty of fully translating the energy-saving and emission-reducing advantages of steel resources into tangible economic competitiveness within the current industry operating environment.

B. Carbon emission restrictions constrain the sustainable development of the steel industry.

Compared to the mature and efficient scrap steel recycling and comprehensive utilization systems in developed countries abroad, the overall level of China's scrap steel industry still requires further enhancement. Carbon emission reduction in the steel industry is pivotal for achieving carbon neutrality. Given that China's crude steel production exceeds half of global output, the low-carbon transformation of China's steel industry is crucial for achieving carbon neutrality both domestically and globally. Considering the practicalities of China's steelmaking processes, it is essential to study the pathways and effects of carbon reduction in the Chinese steel industry, along with conducting thorough cost-benefit analyses of steelmaking technologies. Researchers need to balance environmental and economic benefits while exploring strategies that enable the steel industry to maintain market competitiveness while achieving carbon emission reductions.

III. CONCLUSION, RECOMMENDATIONS, AND OUTLOOK

A. Conclusion and Recommendations

The Chinese steel industry is transitioning from a phase of rapid growth to one of high-quality development, characterized by shifts in development strategies, optimization of economic structures, conversion of growth drivers, and active and prudent advancement towards carbon neutrality. This study creates a comprehensive assessment model for the low-carbon development of the steel industry by analyzing the resource and environmental impacts of different trends in raw steel demand for the year 2060. It evaluates the effects of production structure adjustments, widespread adoption of emission reduction technologies, carbon policies, and carbon-neutral technologies. Using typical environmental emissions as examples, the study reveals regional disparities in these impacts. The main conclusions are as follows:

Resource Consumption: Through the combined effects of multiple emission reduction measures, total energy consumption in the steel industry is projected to decrease by 70% to 76% by 2060 compared to 2020 levels. The application of carbon-neutral technologies will increase the proportion of biomass energy consumption to 69% of total fuel consumption, while electricity consumption shows an increasing trend. With the promotion of hydrogen-based steelmaking, there will be a continuous rise in hydrogen demand. Short-process steelmaking, as a primary technology for the industry's low-carbon future, will increase electricity consumption and the consumption of scrap steel (up to 541 to 679 million tons), while iron ore consumption is expected to decrease by 77% to 81%, and coke recovery by 54% to 63%.

Environmental Emissions: Overall, the impact of emission reduction measures on different environmental pollutants varies. These measures significantly reduce CO2 emissions by 89% to 91% in 2060 compared to 2020 levels, reaching 191 to 237 million tons. The offset effects of carbon emission reduction measures on other atmospheric pollutants cannot be ignored; for instance, the application of carbon-neutral technologies may lead to increases in methane, organic carbon, and volatile organic compound emissions. The trend towards short-process steel production is expected to increase mercury emissions.

Regional Pollution Control and Carbon Reduction Governance: Provincial and facility-level emissions characteristics for typical pollutants such as CO2 and methane exhibit similarities but vary in terms of reduction levels. Mercury emissions show significant regional heterogeneity across three scenarios.

B. Outlook

The conclusions drawn from the aforementioned study provide the following insights for the formulation of high-quality green and low-carbon transformation policies in China's steel industry:

Structural transformations in steel industry production should be systematically planned. The application of emission reduction measures and policy formulation should fully consider regional socioeconomic development paths and the carrying capacity of regional resources and environments, to prevent the "offset" effects on resource and environmental governance caused by emission reduction measures.

The development of short-process pathways in the steel industry should consider diversified strategies for pollution prevention and control. Approaches such as improving scrap

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steel quality and comprehensive pollution prevention and control policies should be explored to reduce risks, such as increased emissions of pollutants like mercury, from the source, achieving synergistic pollutant reduction.

The sustainable development of the electricity system and its interrelation with high-quality, low-carbon development in the steel industry cannot be overlooked. Adjustments in production structure from long to short processes have significant implications for expanding electricity demand. Ensuring clean electricity is particularly crucial for the high-quality, low-carbon transformation of the steel industry. Due to the regional heterogeneity of China's energy supply and consumption, to ensure the reliability and sustainable supply of electricity supply is a major challenge.

Technical upgrades towards zero-carbon targets in the steel industry remain a focal point. Hydrogen energy and CCS technologies are crucial zero-emission technologies for the future of the steel industry, yet they face current technological barriers and high costs. Future efforts should focus on reducing costs through research and development in green hydrogen and CCS technologies to promote their commercial application. Additionally, existing advanced energy-saving and emission reduction technologies are predominantly applied in long processes, with fewer applications in short processes. Future development efforts should therefore intensify research and development of energy-saving technologies specifically tailored for short processes, to adapt to the evolving landscape of the steel industry.

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