Peak carbon emission management for industrial control under the new phase of climate change

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Abstract: This paper systematically analyzes the management pathways for controlling peak carbon emissions in China's industrial sector under the new phase of climate change. The research indicates that industrial carbon emissions account for over 70% of the national total, making it a critical factor in achieving the peak target by 2030. By constructing an E=I×T measurement model, it is predicted that the peak of industrial carbon emissions will occur between 2020 and 2030, with an estimated range of 7 to 8 billion tons. The paper proposes phased, region-specific, and industry-specific peak carbon emission management strategies. It recommends taking 2020 and 2030 as key milestones: in the short term, advancing early peaking in certain industries and regions; in the medium term, achieving overall industrial peaking and establishing a low-carbon development institutional framework; and in the long term, building a comprehensive low-carbon industrial system to balance industrial economic growth with low-carbon development.

Keywords: industrial carbon emissions, peak management, peaking pathways, energy structure, low-carbon transition, climate change

1. Introduction

Regarding climate change, China has explicitly set a medium- to long-term goal of reaching its carbon emissions peak around 2030. The industrial sector accounts for over 70% of the nation's total carbon emissions, making effective control of industrial carbon emissions critical to achieving the peaking target. To this end, it is essential to implement carbon emissions peak management as soon as possible. This involves understanding the development patterns of industrialization and urbanization, integrating efforts to adjust the energy structure, advance industrial supply-side structural reform, and account for regional economic disparities. By proactively managing carbon emissions and overseeing the peaking of industrial carbon emissions across sectors and regions, a balance can be achieved between industrial economic growth and low-carbon development.

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Figure 1

2. Current status of carbon emissions in the industrial sector

2.1. Industrial energy use exceeds 70% of the national total

The industrial sector is the largest energy-consuming department in China, consistently accounting for over 70% of the country's total energy consumption. Starting from the Tenth Five-Year Plan period, industrial and national energy consumption have maintained rapid and synchronized growth. Between 2000 and 2014, national energy consumption increased from 1.47 billion tons of standard coal equivalent (tce) to 4.26 billion tce, while industrial energy consumption rose from 1.03 billion tce to 2.96 billion tce. Both grew by a factor of 1.9, with an average annual growth rate of 7.8%.

2.2. Coal dominates (~70% of energy mix), with industry using ~50% nationally

In recent years, the rapid development of natural gas and new energy sources has led to a decline in the proportion of coal. In 2015, coal consumption accounted for about 64.4% of China's total energy consumption, petroleum and natural gas accounted for about 23.6%, and non-fossil energy consumption accounted for about 12%. The significant high-carbon characteristics remain evident, and the fundamental "coal-dominated" energy structure is difficult to change in the short term. Coal also serves as the primary fuel and raw material for China's industrial sector. According to statistics, in 2012, industrial coal consumption (excluding the power industry) accounted for 46% of the national total, with coking accounting for about 29%, coal chemical industry for 20%, industrial boilers for 30%, and industrial furnaces for 16%.

2.3. Six heavy industries (e.g., steel, cement) consume >70% of industrial energy

Between 2000 and 2014, the energy consumption of six high-energy-consuming industries—steel, building materials, petrochemicals, chemicals, non-ferrous metals, and power—increased from 66.8% to 72.4% of the industrial total, consistently remaining above 70% since 2003. Among these, the steel industry experienced the fastest growth in energy consumption, rising from 200 million tce in 2000 to 690 million tce in 2014, a 2.4-fold increase, accounting for about 23.5% of industrial energy consumption.

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2.4. Industry's fossil emissions: 70% of national total, >85% of industrial total

Carbon emissions in the industrial sector consist of two parts: fossil fuel carbon emissions and industrial process emissions. From 2000 to 2014, fossil fuel carbon emissions from industry increased from 2.37 billion tons to 6.47 billion tons, a rise of 173%. National fossil fuel carbon emissions grew from 3.38 billion tons to 9.31 billion tons, an increase of 175%. The proportion of industrial fossil fuel carbon emissions to national emissions decreased slightly from 70.1% in 2000 to 69.4% in 2014. In 2014, industrial fossil fuel carbon emissions accounted for 86% of total industrial emissions. Industrial process emissions in 2014 were approximately 1 billion tons, making up about 14% of total industrial emissions. Total industrial carbon emissions in 2014 were around 7.5 billion tons. Overall, before 2012, the growth rate of industrial carbon emissions consistently outpaced that of national carbon emissions. Since 2012, influenced by factors such as a slowdown in industrial economic growth and overcapacity in high-energy-consuming industries, the growth rate of industrial carbon emissions has decelerated, falling below the national growth rate.

3. Main factors influencing industrial carbon emission control

3.1. Development stage impacts industrial carbon control efficiency

The development stage includes the processes of industrialization and urbanization. At different stages, the difficulty of controlling industrial carbon emissions varies due to differences in economic growth rates, industrial structure, and technological progress. According to patterns observed in developed countries, during the early stages of industrialization, light industry develops first, leading to slow growth in industrial carbon emissions. Entering the mid-stage, as demand for fixed asset investment and infrastructure construction surges to meet the needs of industrialization and urbanization, heavy and chemical industries accelerate, and carbon emissions also increase rapidly. In the later stages, as infrastructure construction is completed, high-end manufacturing and services begin to develop, carbon emissions start to decline, and a peak emerges. Following this pattern, controlling carbon emissions too early or too late is detrimental to the development of a country or region. Only when approaching or entering the later stages of industrialization, when the carbon emissions peak is likely to occur, can proactive and timely management of industrial carbon emissions genuinely ensure sustainable development.

During the Tenth and Eleventh Five-Year Plan periods, the proportion of heavy and chemical industries in China increased rapidly, leading to a swift rise in industrial carbon emissions, with the peak unlikely to occur during this time. In the later years of the Twelfth Five-Year Plan period, China's economic situation underwent significant changes. The service sector began to surpass industry in proportion, per capita GDP reached $8,000, and the country entered the later stages of industrialization. This shift is characterized by an upgrade in consumption structure, a slowdown in demand for high-carbon emission products such as steel and cement, an increase in demand for high-end industrial goods, services, and green environments, and structural reforms on the industrial supply side. The likelihood of a carbon emissions peak occurring has increased, presenting an opportunity to guide and implement carbon emissions peak management accordingly.

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Figure 2

3.2. Energy mix timing shapes industrial carbon control

Coal serves as the primary fuel and raw material for China's industry and is also a high-carbon emission energy source. The proportion of coal in the total energy consumption determines the carbon emissions per unit of energy consumed in the industrial sector. A larger proportion results in higher carbon emissions per unit of energy, while a smaller proportion leads to lower emissions.

Historically, coal has accounted for nearly 70% of China's energy structure, making it a significant factor contributing to the high level of industrial carbon emissions. In recent years, the rapid development of natural gas and new energy sources has begun to reduce coal's share, but the "coal-dominated" energy structure remains difficult to change in the short term. This indicates that transitioning China's industrial carbon emissions from high to low levels will be a gradual process and cannot be achieved overnight.

3.3. Regional gaps shape industrial carbon control

China's industrial economy is more developed in the eastern regions compared to the west, and in the south compared to the north. Additionally, low-end traditional manufacturing and heavy industries account for a large share, while high-end advanced manufacturing and high-tech industries hold a smaller proportion. From a regional perspective, developed areas possess greater resources and capabilities to control carbon emissions compared to less developed ones. This suggests that China's approach to achieving industrial carbon emissions peaking should involve allowing certain regions to reach their peaks first, followed by others, thereby gradually realizing the goal region by region. From an industrial standpoint, high-carbon emission sectors such as steel, building materials, petrochemicals, chemicals, non-ferrous metals, and power generation occupy a large proportion and substantial share of total emissions. It is necessary to prioritize their control, indicating that the peaking of carbon emissions should be advanced step by step across different industries.

4. Industrial carbon peaking pathway model research

4.1. Industrial carbon peaking model: setup & parameters

A calculation model is constructed based on the primary equation $E = I \times T$, where:

E represents total industrial energy consumption;

I represents industrial added value;

T represents the energy intensity of industrial added value.

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These three variables are closely related to industrial carbon emissions, economic growth rates, industrial structure, and technological progress.

Table 1 Key Parameter Settings for the Carbon Emission Model, 2010–2035

	2010~2015	2015~2020	2020~2025	2025~2030
Average Annual Growth Rate (%)	8	7	6	5
Rate of Decrease in Energy Intensity (%)	19	19	18	17

Table 2 Energy Structure Parameter Settings for the Carbon Emission Model, 2015–2035

	2015	2020	2030	2035
Proportion of Non-Fossil Energy (%)	11	15	20	25

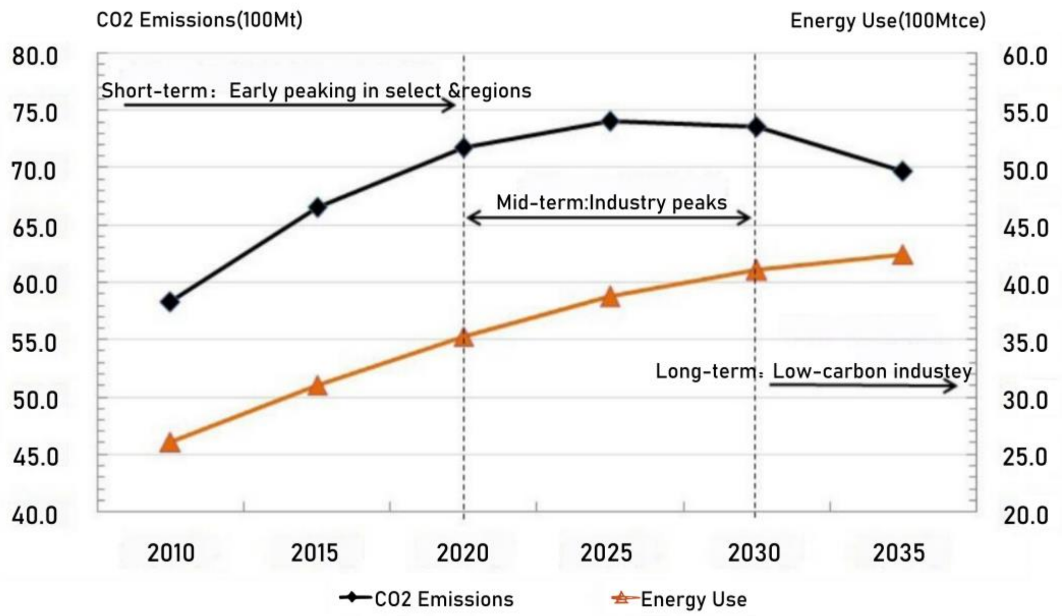

Figure 3 Trends and Peak of Industrial Carbon Emissions in China, 2010-2035

Taking into account the circumstances of the 11th and 12th Five-Year Plan periods, and referencing relevant planning policy documents, the model parameters are set as follows:

Based on the Industrial Transformation and Upgrading Plan and the 12th Five-Year Plan for Industrial Energy Conservation, the annual average growth rate of industrial added value for 2010–2015 is set at 8%, and the rate of decrease in energy intensity of industrial added value is set at 19%. In line with the goal proposed at the 18th National Congress of the Communist Party of China to double the 2010 GDP by 2020 and reduce carbon intensity per unit of GDP by 40%–45% from 2005 levels by 2020, the annual average growth rate of industrial added value for 2015–2020 is set at 7%, with a 19% decrease in energy intensity of industrial added value. Drawing on the post-industrialization economic growth trends of major industrial countries worldwide, the growth rate of industrial added value and the rate of decrease in energy intensity for 2020–2035 are set as detailed in Table 1.

In accordance with the targets of the 12th Five-Year Plan for Energy and the 2020 renewable energy development goals, the proportion of non-fossil energy is set to reach 15% by 2020. Based on the U.S.-China Joint Announcement on Climate Change, the proportion of non-fossil energy is set to reach 20% by 2030. Considering the breakthrough progress in new energy technology innovation and industrialization, China's non-fossil energy supply is expected to maintain relatively rapid growth after 2020, with a projected proportion of 25% by 2035, as detailed in Table 2.

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4.2. Measurement results and analysis based on the model

Based on the above, the industrial carbon emissions in China from 2010 to 2035 are estimated. Figure 1 illustrates the model results.

The following conclusions can be drawn from Figure 1:

First, China's industrial carbon emissions are projected to peak between 2020 and 2030. This conclusion supports China's goal of reaching the peak by 2030, indicating that the industrial sector can achieve this target through dedicated efforts. It also suggests that China's industry is currently approaching or entering the later stages of industrialization, creating favorable conditions for proactively controlling carbon emissions in the industrial sector and implementing carbon emission peak management.

Second, the peak of China's industrial carbon emissions is estimated to be between 7 to 8 billion tons. Considering the industrial carbon emissions of 6.47 billion tons in 2014 and aiming to peak by 2030, the industrial sector has a remaining carbon emission allowance of approximately 500 million to 1.5 billion tons over the next 15 years. If the development pattern of the past 15 years (with an average annual growth rate of industrial carbon emissions of about 7%) continues, this allowance will be insufficient. Therefore, advancing low-carbon development in industry and proactively controlling carbon emissions is imperative. Additionally, given that industrialization and urbanization are still ongoing and industrial economic growth must be sustained, the overall situation for controlling industrial carbon emissions in China remains challenging.

Third, industrial energy consumption is expected to continue growing slowly after the peak of industrial carbon emissions, or post-2030. This indicates that the total industrial output in China will need to maintain an upward trend, and the development process is far from complete.

Fourth, 2020 and 2030 are two critical milestones for carbon emission management. Around 2020, industrial carbon emissions are projected to begin slowing, suggesting that certain industrial sectors will reach their peak around this time. After 2030, overall industrial carbon emissions are expected to show a clear downward trend, indicating that China has the potential to establish an advanced low-carbon industrial system after 2030.

5. China's industrial carbon control focus: next 5-15 years

5.1. Overall Framework for China's industrial carbon emission control

Through research and analysis, it is recommended that China's industrial carbon emission control should take 2020 and 2030 as two key milestones, with efforts focused on the short term (next 5 years), medium term (next 10 years), and long term (next 15 years).

5.1.1. Short term

Treat 2015–2020 as the exploration period for industrial carbon emission peak management. Proactively control carbon emissions, promote early peaking in certain industries and regions, and explore carbon emission peak management to accumulate experience for achieving the overall industrial carbon emission peak in the future.

5.1.2. Medium term

Treat 2020–2030 as the critical period for transitioning China's industry from a high-carbon emission model to a low-carbon one. Through effective carbon emission peak management, advance the early peaking of industrial emissions. During this period, establish a fundamental institutional framework for low-carbon industrial development, preliminarily achieving low-carbon transformation in industrial technology, processes, equipment, products, and policy systems.

5.1.3. Long term

After 2030, focus on building a mature and advanced low-carbon industrial system, ultimately establishing a large-scale modern low-carbon industrial system to enhance the low-carbon competitiveness of China's industry.

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5.2. China's industrial carbon control strategies: 13th five-year plan

First, continue to prioritize and strengthen climate change mitigation efforts in the industrial sector by researching and formulating a medium- to long-term strategy for industrial response to climate change by 2030. Second, study and establish a phased, region-specific, industry-specific, and enterprise-specific institutional system for low-carbon industrial development, with a focus on promoting carbon emission control in key industries such as steel and cement. Third, initiate industrial carbon emission peak management in selected industries (e.g., steel, cement) and regions (e.g., Beijing, Shanghai) to explore management practices. Fourth, fully leverage the role of carbon markets and strengthen market mechanisms in industrial carbon emission control. Fifth, enhance the low-carbon competitiveness of enterprises by improving carbon asset management and promoting pilot demonstrations of low-carbon enterprises.

6. Conclusion

Peak management of industrial carbon emissions is a critical initiative for China to address climate change and achieve high-quality development. Given the characteristics of the post-industrialization development stage and the reality of a coal-dominated energy structure, it is essential to proactively guide and control carbon emissions through phased, region-specific, and industry-specific refined management. This approach will ensure industrial economic growth while promoting a low-carbon transition. The next 5 to 15 years represent a critical window for achieving the peak in industrial carbon emissions. During this period, it is imperative to establish a robust low-carbon development institutional system, leverage market mechanisms, and enhance the low-carbon competitiveness of enterprises. Ultimately, this will enable a historic transition from a "high-carbon industry" to a "low-carbon industry," contributing China's solution to global climate governance.

Figure4

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