Original Research Article

Research on the collaborative mechanism and multi-scenario path of pollution reduction and carbon reduction in megacities

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Abstract: With the aggravation of global climate change and environmental pollution, pollution reduction and carbon reduction has become an urgent global task. Megacities, as the main source of energy consumption and pollution emissions, face complex challenges in emission reduction. Based on the scenario-driven theory, this paper deeply analyzes the mechanism of pollution reduction and carbon reduction in megacities, and explores the industrial synergies and their optimization path. The STIRPAT model and collaborative control coordinate system were used to simulate the emission reduction effect in different scenarios, quantify the impact of various emission reduction measures on carbon emissions, and evaluate the effect of various collaborative control measures. The research results show that there are significant synergistic effects between the three scenarios of energy structure adjustment, transportation emission reduction and building energy conservation improvement. Reasonable policies and technical measures can effectively reduce carbon emissions and pollutant emissions, providing a scientific basis and practical path for pollution reduction and carbon reduction in megacities

Keywords: Pollution reduction and carbon reduction; Megacities; Synergy mechanism; Industrial synergy; STIRPAT model;

1. Introduction

Global climate change and environmental pollution are becoming increasingly serious, and pollution reduction and carbon reduction has become an urgent global task. As the largest developing country in the world, China is facing huge environmental pressure and emission reduction challenges, and pollution reduction and carbon reduction has risen to the national strategic level of[1].megacities, such as Beijing and Shanghai, are the core regions of China's economy, but they are also the main source of energy consumption and pollution emissions[2-4]. These cities are densely populated, complex industrial structure, large energy consumption, and the task of pollution reduction and carbon reduction is arduous, facing many problems such as complex energy structure adjustment, arduous transportation emission reduction task, and difficulties in building energy efficiency improvement

The academic circle has explored the synergistic effect of pollution reduction and carbon reduction. Domestic research focuses on policy optimization and industrial transformation. For example, Li Yunyan et al. analyzed the characteristics of pollutants and carbon emissions in the Beijing-Tianjin-Hebei urban agglomeration, pointing out that energy consumption intensity and total amount of energy consumption are the key factors. Yu Shan et al. quantified the driving role of energy intensity of manufacturing industry in Beijing through LMDI model, and confirmed its effect in pollution reduction and carbon reduction. In foreign studies, Yetan et al. sorted out the urban sustainability assessment method and pointed out the dual role of cities in the process of pollution reduction and carbon reduction. Erickson et al proposed technical screening tools for urban greenhouse gas emission reduction, emphasizing the synergistic effect of cross-departmental integration measures

2. Clear scenes of pain points of pollution reduction and carbon reduction in megacities

2.1. megacities are refining the pain points of pollution reduction and carbon reduction

In the process of promoting pollution reduction and carbon reduction, the main pain points faced by megacities include:

(1) The adjustment of the energy structure is complex. In megacities have huge energy demand, the promotion of clean energy is under great pressure, and there are cost and technical restrictions in the transformation process. In addition, ensuring the stability of the energy supply requires better management, leading to a slowdown in the pace of transition.

(2) The task of transportation emission reduction is arduous. With densely populated and with large traffic flow, vehicle exhaust is one of the main sources of air pollution and carbon emissions. For example, Shenzhen has made progress in the optimization of new energy vehicles and public transportation, but the layout of charging facilities lags behind, it is inconvenient to use clean transportation in the urban and rural fringe, and the traffic management still needs to be further optimized.

(3) Difficulties in improving the energy efficiency of existing buildings. China has a huge stock of existing buildings in megacities, and the improvement of energy efficiency is faced with technical and financial difficulties. The high proportion of energy consumption in old buildings and the insufficient market incentive mechanism restrict the application of energy-saving technology.

2.2. Preliminary solutions of combining scene-driven methods

Based on the above pain points, this section puts forward preliminary solutions by combining the three scenarios of “energy structure adjustment”, “transportation emission reduction” and “building energy conservation improvement”.

(1) Energy structure adjustment: The focus is to build a distributed clean energy system, optimize energy efficiency, and reduce the dependence on traditional fossil energy. Promote distributed photovoltaic, wind-solar complementary power generation and energy storage technologies to meet the green energy needs of the building and transportation sectors.

(2) Emission reduction in transportation: Focus on the construction of intelligent transportation system and the promotion of green vehicles. Promote low-carbon travel, reduce emissions and improve air quality by optimizing traffic signal systems, increasing new energy and buses.

(3) Building energy conservation improvement: including renovation of existing buildings and design of new green buildings, reducing energy consumption and improving building energy efficiency through external wall insulation and window upgrading.

3. Theoretical path analysis of industrial interconnection and collaboration driven by the scenario

3.1 Cross-industry coordination mechanism

In the process of achieving the goal of pollution reduction and carbon reduction in megacities, the cross-industry coordination mechanism promotes sustainable development through resource integration, technological innovation and market cooperation. For example, Hefei has promoted green development through the technology innovation platform, and Shenzhen has promoted the popularization of green technologies through carbon footprint certification and carbon neutral demonstration zone.

3.2. Collaborative emission reduction mechanism of the upstream and downstream of the supply chain

The collaborative emission reduction mechanism of the upstream and downstream enterprises in the supply chain is very important in the green and low-carbon development. Through cooperation, enterprises can effectively control and reduce the overall carbon supply chain. The collaborative emission reduction mechanism of upstream and downstream enterprises is crucial in green and low-carbon development. Through cooperation, enterprises can effectively reduce their overall carbon emissions. For example, the Shanghai Green Supply Chain case and ZTE's carbon neutral airlift project show how to promote the green transformation of the supply chain through joint emission reduction and optimized carbon management.

Despite some results, there is still room for optimization. It is suggested to strengthen policy support, improve the information sharing mechanism, and strengthen supplier management and training, to ensure the transparency of carbon emission data, and to promote the green transformation of the whole chain.

These cases show that the supply chain coordinated emissions reductions can help companies achieve sustainable development and contribute to tackling climate change.

3.3. Case study on collaborative emission reduction in industrial interconnection

Industrial interconnection has played an increasingly prominent role in coordinated emission reduction, and the successful experience provides valuable reference for urban and industrial development. Here are a few case studies:

Through the whole-chain carbon emission reduction strategy, Yili Group optimizes the use of energy, builds a zero-emission factory, and promotes the transformation of the industrial chain to low-carbon. The group has introduced solar photovoltaic and waste harmless treatment technology, and developed environmentally friendly packaging materials to reduce the carbon footprint.

4. Analysis of the synergistic benefit mechanism and the effect

4.1. Mechanism analysis of cooperative control coordinate system

In the mechanism analysis of the collaborative control coordinate system, the collaborative control coordinate system is constructed to represent the greenhouse gas emission reduction through the vertical axis, and represents the emission reduction of air pollutants through the horizontal axis. In this way, the synergies of different emission reduction measures can be quantitatively assessed, helping to identify effective emission reduction measures and optimize the emission reduction paths. The elasticity coefficient is very important in this analysis, and its calculation formula is the formula (1):

$$ET = \frac{\Delta P/P}{\Delta C/C} \tag{1}$$

Among them, it is $\Delta P/P$ $\Delta C/C$ the relative change rate of air pollutant emissions, that is, the ratio of the change of air pollutant emissions and the initial emissions before and after the implementation of a certain measure. It is the relative rate of change of greenhouse gas emissions, that is, the ratio of the change of greenhouse gas emissions and the initial emissions before and after the implementation of a certain measure.

When a measure is located in the third quadrant of the cooperative control coordinate system, it means that the measure achieves both effective emission reduction of greenhouse gases and air pollutants, which demonstrates its significant synergistic effect.

After build the collaborative control coordinate system, can apply STIRPAT model to analyze the specific application mechanism of pollution reduction and carbon reduction, STIRPAT model is used for the analysis of population, income and technical factors on the environment impact of statistical model, through the introduction of space and time weighted elements, regional population size, economic development level and technical level of variables, STIRPAT model can more accurately predict carbon emissions under different scenarios. The basic form of this model is the formula: (2):

$$E = \alpha + \beta_1 P + \beta_2 A + \beta_3 T + \epsilon$$

Among them, is the environmental $EPAT\alpha\beta_1\beta_2\beta_3\epsilon$ impact (such as carbon dioxide emissions), for the population, for the wealth, for the technology, is the model parameters, is the error term.

4.2. Analysis of the cross-elasticity mechanism of pollutant emission reduction

The cross-elastic mechanism of pollutant emission reduction evaluates the linkage effect of emission reduction measures on other pollutants, and optimizes the emission reduction strategy. For example, the promotion of new energy vehicles in Shanghai not only reduces CO_2 emissions, but also reduces the emissions of other air pollutants and improves the efficiency of pollution control.

In the industrial field, the cement industry reduces CO_2 and NO_x emissions by replacing the emission reduction efficiency. Analysis in Beijing shows that the emission reduction potential of SO_2 and NO_x is more than 20%, and that of CO_2 is about 7%.

In the field of transportation, Beijing has effectively reduced the emissions of CO_2, NO_x and PM through a variety of emission reduction policies, and improved the air quality.

Reasonable use of cross-elastic mechanism can optimize emission reduction strategies, improve the benefits of coordinated emission reduction, and provide support for future environmental policy formulation.

5. Case analysis of megacities

5.1. Collaborative mechanism of pollution reduction and carbon reduction in Guangzhou city

Guangzhou city promotes pollution reduction and carbon reduction through policy, technological innovation and market cooperation. The municipal government implements the strategy of energy conservation and carbon reduction, improves the energy efficiency of key energy-using units, and promotes the development of circular economy and comprehensive energy services. The Carbon Peak Implementation Plan strengthens the responsibilities of all district governments and promotes the green transformation in industries, transportation, construction and other fields.

In terms of technological innovation, Guangzhou has made remarkable achievements in the field of water treatment and efficient wastewater treatment, and provided a demonstration for the national pollution reduction and carbon reduction. In terms of market cooperation, Guangzhou Carbon Emission Trading Center has promoted the development of the carbon trading market, and Nansha Economic and Technological Development Zone promotes collaborative innovation through green finance support.

In recent years, Guangzhou has made remarkable achievements in air and water environment management, providing valuable experience for other cities.

5.2. Collaborative mechanism of pollution reduction and carbon reduction in Tianjin

Tianjin promotes the green and low-carbon transformation through industrial interconnection, resource integration and policy innovation. The coordination with Beijing and Hebei has promoted the coordinated development of the industrial chain and promoted the rise of emerging economies. In terms of resource integration, the municipal government improves the efficiency of resource utilization and optimizes the development of territorial space.

Policy innovation is the key. Tianjin provides legal guarantee through the Regulations on the Promotion of Carbon Peak and Carbon Neutral Cooperation, and establishes a carbon emission trading market as a pilot carbon market to encourage enterprises to adopt cleaner production processes and promote green transformation.

Tianjin city has successfully built a green and low-carbon demonstration model, which provides a reference for the green transformation of other cities, and contributes to the realization of the goal of carbon peak and carbon neutrality.

6. Summary

Based on the scenario-driven theory, this paper deeply analyzes the coordination mechanism of pollution reduction and carbon reduction in megacities, and discusses the interactive relationship and optimization path of the three key fields of energy structure adjustment, transportation emission reduction and building energy conservation improvement. Through the STIRPAT model and synergistic control coordinate system, the study quantitatively evaluated the synergistic effect of various emission reduction measures, and revealed the dynamic interactive mechanism of pollution reduction and carbon reduction in different scenarios. The results show that reasonable policy measures and technological innovation can produce synergistic effects in multiple dimensions, significantly improve the efficiency of emission reduction, and promote the green and low-carbon transformation of megacities.

Future research can further deepen the dynamic simulation of the synergy mechanism, explore the application of more practical cases, and provide more operational paths and strategies for other cities in the process of achieving the goal of pollution reduction and carbon reduction.

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