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Pathways and Innovative Mechanisms for Achieving Urban Carbon Neutrality

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Abstract: This paper discusses the problems of the traditional carbon emissions trading mechanism, such as failing to effectively incorporate carbon sinks into the carbon market and failing to adequately incentivise the economic and ecological development of cities, and proposes a new urban carbon neutral trading system to solve these problems. The new urban carbon neutral trading system is based on the city as a unit, and by fully integrating carbon sinks into the trading system, it adopts the market mechanism to regulate the balance between carbon emissions and carbon sinks, so as to realise the coordinated development of the urban economy and the green environment. In addition, this study develops a comprehensive evaluation index system for urban carbon neutrality, and uses big data and intelligent analysis techniques to improve the accuracy and real-time performance of urban carbon management. These innovations not only help strengthen urban environmental management, but also promote urban economic transformation and provide theoretical support for sustainable regional economic growth.

Keywords: carbon neutrality, carbon credits, carbon sinks, urban economy

1. Introduction

A carbon emissions trading mechanism is a policy tool adopted by governments or international organisations to reduce greenhouse gas emissions and promote a low-carbon economy. However, there are some shortcomings and challenges associated with this mechanism.

Firstly, the existing carbon emissions trading mechanism does not fully incorporate the carbon sink market, and fails to create a balance between carbon dioxide and harmful gases "absorption" and "remittance" on a macro level. Emphasis on emission reduction without effectively integrating carbon sinks into the market is not only detrimental to the growth of enterprises and even the economy, but also to the healthy and sustainable development of the macro-ecological environment.Deng et al. pointed out that, although China's carbon sinks are rich in resources, they are facing difficulties in converting them into economic resources, and the supply and demand of the carbon trading market are not effectively connected, which has resulted in the value of carbon sinks being not fully utilised[1].

Secondly, the existing carbon emissions trading system lacks the inherent economic and ecological power to promote the economy and ecology in various regions, especially in large cities, and has insufficient ability to generate revenue for the city's economy and finances, nor can it substantially

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improve the ecological environment.Zhang and Fan found that although the existing carbon trading mechanism can theoretically bring economic benefits to cities, it is often difficult to achieve the expected results in practice[2]. Huang and Chen also point out that the carbon trading system did not significantly increase the overall green productivity of pilot cities[3]. This suggests that existing mechanisms need to be adjusted. This suggests that existing mechanisms need to be adapted to better incentivise cities to develop green economies and ecosystems.

Third, traditional carbon emissions trading suffers from cross-city 'carbon leakage', firms may move their production and emissions to regions with no or lower carbon emission regulations, thus defeating the goal of reducing total global GHG emissions. a case study by Zhang et al. suggests that China's carbon trading system may unintentionally exacerbate intra-industry competitive distortions and carbon leakage[4]. This is supported by Yu et al.'s study, which suggests that developing countries' carbon emissions trading systems may have accelerated carbon leakage through outward foreign direct investment (OFDI)[5].

Despite these drawbacks and challenges, the current carbon emissions trading mechanism is still considered an important tool that can play a positive role in reducing greenhouse gas emissions. In order to address its series of drawbacks and problems so that it can better promote the synergistic development of the economy and ecosystems in different cities or regions, one feasible option is to innovate the carbon trading mechanism by fully integrating carbon sinks into the carbon emissions trading system. The carbon sink market refers to the adsorption and storage of carbon emissions in the atmosphere through the protection, enhancement or restoration of ecosystems (e.g., forests, wetlands and land), and the use of these carbon emission reductions or negative emissions for carbon emissions trading. Although carbon sink markets exist in countries around the world today, such as the Clean Development Mechanism (CDM) or China Certified Emission Reduction (CEER) proposed by the Kyoto Protocol, their development has been in the doldrums for a long time.

The contributions and innovations of this paper are: firstly, a new urban carbon neutral trading model is proposed, which fully integrates carbon sinks trading into the market trading system and uses the market mechanism to regulate the balance between carbon emissions and carbon sinks. Secondly, a comprehensive urban carbon neutral evaluation system has been developed to improve the accuracy and real-time monitoring capability of urban carbon management. These innovations provide data support and decision-making tools for policymakers and urban planners, effective tools for achieving carbon neutrality targets, and feasible business models and policy references for global carbon emission reduction.

2. New urban carbon neutral trading system

The new carbon emissions trading model completely jumps out of the initial share allocation thinking framework, and makes emissions and sinks equalise or emissions do not exceed sinks on a macro level, which not only promotes the sustainable development of the ecological environment, but also improves the market mechanism and avoids the shortcomings of the traditional carbon emissions trading mechanism.

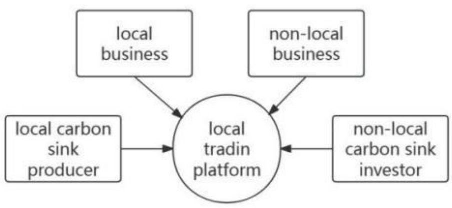

Figure 1: Urban carbon emissions trading market structure.

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The new model is city-based, as shown in Figure 1, and the mechanism is designed to make a city as micro-carbon neutral or carbon-neutral as possible. Unlike the traditional allocation of quotas for carbon credits, the new trading mechanism does not require quotas; instead, carbon emissions are naturally determined by carbon sinks. That is, carbon emissions are the demand and carbon sink construction is the supply. Enterprises buy carbon emission targets directly from local carbon sink producers (forest owners, charitable organisations, silvicultural enterprises, etc.), and trading takes the form of online or offline on local platforms. Carbon emissions that are not sufficiently supplied locally can be purchased from surplus carbon sinks outside the country, and local surplus carbon sinks can be sold to enterprises outside the country. Of course, enterprises can also create carbon sinks by afforestation on the one hand, and produce carbon emissions in general to achieve carbon neutrality. If the current amount of carbon sinks in each city really can't meet the carbon emissions, enterprises can choose "carbon credit", that is, overdraft some carbon emissions in the future, while choosing a certain period of time in the future to complementary afforestation or indirectly investing in carbon sinks, to compensate for their excess emissions. The transaction price is determined by the market, and the amount of carbon sinks or the potential of carbon sinks can be derived from relevant measurement models.

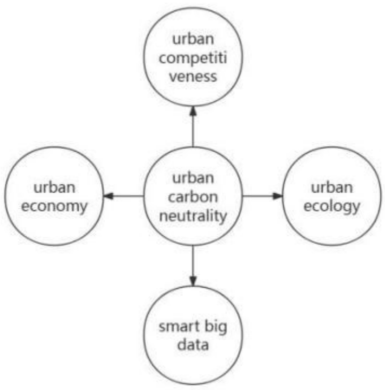

Figure 2: Expectations for a new urban carbon emissions trading market.

As shown in Figure 2, the new carbon neutral trading market is based on the city as a unit, and factors such as ecological sustainability, economic development, and smart big data are used as multiple purposes to enhance the competitiveness of cities and human civilisation.

3. Macro-framework: a comprehensive evaluation indicator system for urban carbon neutrality

In order to measure the carbon neutrality level of different cities, we have developed an evaluation system covering the key areas of energy, transport, buildings and natural carbon sinks to accurately quantify the carbon management of cities and provide data support for policy formulation and adjustment. When establishing an urban carbon emission and sink indicator system, the following key areas need to be considered: energy sector, including urban energy consumption, proportion of renewable energy, and energy efficiency improvement; transport sector, including transport emissions, public transport utilisation rate, and proportion of non-motorised roads; building sector, including building energy efficiency standard compliance rate, and building land use type; and natural carbon sinks, including the extent of urban greenland coverage, and the health of urban forests and wetlands. health of wetlands.

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Table 1 shows the comprehensive carbon neutral scoring framework for cities constructed in this paper, which takes into account not only the ecological environment, but also the attractiveness of carbon-neutral investments and the potential for future low-carbon governance.

Table 1: Urban carbon neutral composite scoring framework.

Target indicators	Level indicators	Secondary indicators	Interpretation of indicators
Integrated city carbon neutral score S	Carbon Neutral Instant Score S_1	Local instantaneous carbon sink S_{11}	
		Local instantaneous carbon emissions S_{12}	
		Carbon pollution intensity S_{13}	is the amount of carbon emitted per unit of incremental production
		Carbon accumulation S_{14}	Refers to the accumulation of carbon, indicating the impact of carbon emissions on the environment.
		Carbon offset S_{15}	Ability to transfer carbon molecules to another region
		Net emission (reduction) growth rate S_{16}	
	Carbon Neutral Investment Score S_2	Local carbon price S_{21}	Local purchase price of carbon emissions
		Sell Carbon Price S_{22}	Field purchase price of carbon emissions
		Import carbon price S_{23}	Prices for the purchase of field emission rights
		Local carbon demand S_{24}	Local demand for carbon credits
		Export carbon demand S_{25}	Local demand for carbon credits by foreign enterprises
		Urban Management Support S_{26}	Local government support policies for carbon emissions trading, etc.
		Carbon sink cost S_{27}	Costs of afforestation, industrial carbon sinks, etc.
		Trading platform sophistication S_{28}	Local trading platforms for local carbon sink investments
	Carbon Neutral Potential Score S_3	Treeable wasteland S_{31}	More wasteland means more potential for future carbon sinks
		Reducible emission credits S_{32}	A high level of reductions suggests room for future progress
		Business and Individual Participation S_{33}	A low level of participation indicates a high potential for future markets

As shown in Table 1, there are three level 1 indicators: the carbon neutral immediate score, the carbon neutral investment score and the carbon neutral potential score. The first one measures the city's carbon neutrality at the present time and consists of traditional ecological and environmental indicators, which are detailed in the table's level 2 indicators; the second one consists of a series of price or cost factors, which reflect the attractiveness of the city to make low-carbon investments at the present time; and the third one shows the future potential for carbon sinks. The more resources there are, such as barren hills and wasteland, the more room there is for future afforestation.

One of these indicators is the traditional industrial carbon emission indicators, such as the major indicators in S_1 , which follow the traditional carbon footprint calculation method, which is not difficult in the era of big data. The second category is economic indicators, which indicate the economic value of carbon neutral investments, which is ignored by traditional methods. Because the traditional method is a quota system, not a market mechanism, it does not pay attention to the positive

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economic benefits that carbon sink-related investments and carbon neutral markets can bring to cities. The third type of potential indicator, which represents the future ecological carrying capacity, i.e., the pollution control capacity, requires the development of models to account for it.

The main indicators are selected below to demonstrate the calculation methodology. For example, for S_{12} the framework for calculating urban carbon emissions is as follows:

Total Carbon Footprint = Local Direct Carbon Emissions + Emissions from Field Production (Locally Generated Externalities) + Indirect Service Carbon Emissions

Direct carbon emissions include those generated directly from the living and productive activities of residents, businesses and institutions within the geographic boundaries of the city. Local direct carbon emissions typically come from the following areas:

(1) Biological respiration and movement: comes from the natural life activities of organisms.

(2) Local transport equipment: including tailpipe emissions from private transport and public transport.

(3) Local construction and industry: This includes carbon emissions from construction and industrial processes, such as building construction and manufacturing.

(4) Fossil energy use: This includes carbon emissions from the direct combustion of fossil energy for electricity, heating, cooking and other activities in units, households and businesses.

(5) Plant combustion (forest fires and straw burning, etc.) and waste decomposition: including carbon emissions from landfills and incineration.

In the past, local direct carbon emissions have been calculated using energy use and activity data for each sector, multiplied by a corresponding carbon emission factor. In the smart era, more detailed calculations can be made by refining big data on resources and the environment at all levels.

Emissions from external production (locally-generated externalities): The share of carbon emissions from external production, and thus emissions from external sources, in the food, clothing, housing and energy consumption of local residents. For example, if a city relies on an external region for electricity supply, its indirect carbon emissions should also be taken into account.

Indirect service carbon emissions: This includes carbon emissions that result indirectly from goods and services consumed by residents, businesses and institutions within cities. Indirect carbon emissions typically include carbon emissions from the production, transport and disposal of goods and services consumed by residents and organisations within cities, such as food, clothing, electronics and other products.

The large amount of data that needs to be collected in order to calculate a comprehensive carbon neutral score for a city covers everything from local carbon sinks and emissions to economic and administrative support. Detailed data collection includes key areas such as energy consumption patterns, transport system efficiency, building behaviour, and the status of natural carbon sinks. The evaluation system also requires real-time monitoring of price dynamics in the carbon market, the level of government policy support, and the cost of building and maintaining carbon sinks. Such multi-dimensional data collection and complex calculation methods ensure that the scoring system is comprehensive and accurate, allowing city managers to adapt policies and strategies to the actual situation in order to achieve more effective carbon neutrality goals.

4. Conclusion and Policy recommendations

The new urban carbon neutral trading system proposed in this article aims to solve the problems existing in the traditional carbon emissions trading mechanism by comprehensively integrating carbon sinks into the carbon market strategy. By adjusting the balance of carbon emissions and carbon sinks through market mechanisms, this system not only helps promote the development of urban green economy, but also promotes the coordinated growth of ecology and economy. In addition, by developing a comprehensive urban carbon neutrality evaluation index system and combining big data and intelligent analysis technology, the accuracy and response speed of urban carbon management can be significantly improved.

Based on the above research and analysis process,this paper puts forward the following countermeasure suggestions:

4.1. Improving the integration of carbon sink markets

Governments should first clarify the definition and categorisation of carbon sinks, establish a comprehensive carbon sink certification and registration system, and ensure the quality and transparency of carbon sink projects. Policymakers need to formulate clear guidelines, including the protection and management of natural carbon sinks such as forests and wetlands. At the same time, a docking platform for market demand and supply needs to be established to facilitate effective exchanges and transactions between the supply and demand sides of carbon sinks.

4.2. Establishment of a database on urban carbon neutral indicators

The Government should establish a database of urban carbon neutral indicators that integrates advanced technologies to support and optimise the urban carbon neutral evaluation system. The database should make use of big data analytics, artificial intelligence and Internet of Things technologies to collect and process data on energy consumption, transport patterns, building efficiency and natural carbon sinks to provide accurate and real-time carbon footprint information. In this way, the relevance and effectiveness of policymaking can be enhanced, thereby strengthening nationwide carbon reduction efforts.

4.3. Establishment of a standardised carbon-neutral city comparison framework

In order to promote inter-city carbon reduction efforts and effective policy implementation, a standardised city comparison framework can be established to compare carbon emissions between cities through uniform indicators and data. This framework should include key indicators, such as per capita carbon emissions, to quantify and compare the carbon intensity of different cities.Such comparisons will not only help to identify leaders and laggards in the field of carbon emission reduction, but also motivate cities to take more effective measures and jointly promote the achievement of national and global carbon neutrality targets.

4.4. Implementation of a mechanism for assessing the carbon neutral performance of cities

The impact of urban climate policies can be effectively assessed through the implementation of a comprehensive set of policy impact assessment mechanisms, which includes quantifying the specific effects of policies by collecting and analysing relevant data before and after the implementation of new policies, such as transport emissions before and after changes in public transport policies. Using advanced data analytics and big data platforms, the real-time impact of policy changes on carbon emissions and other environmental indicators can be accurately tracked. Such assessment not only helps policymakers understand the actual effectiveness of measures, but also enhances transparency and accountability in urban management.

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