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Original Paper

Research on Urban Low-Carbon Economy

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Abstract

The urban low-carbon economy represents a development model focused on decoupling economic growth from carbon emissions, emphasizing the integrated application of technological innovation, institutional innovation, and industrial restructuring. This paper examines development pathways through policy guidance, institutional innovation, technological advancement, industrial upgrading, public participation, and awareness enhancement. Governments should refine policies and regulations to strengthen support for low-carbon development. Technological innovation serves as a critical driver, necessitating increased investment in low-carbon R&D, encouragement of corporate green innovation, active cultivation of emerging industries, and industrial structure optimization. Public engagement and awareness are fundamental safeguards, requiring education to promote understanding of low-carbon concepts and lifestyle adoption. Cities develop distinctive models based on socio-economic characteristics and resource-environmental endowments: Wuhan established theoretical foundations integrating sustainability principles; Langfang leveraged its geographic advantage within the Beijing-Tianjin-Hebei strategy to achieve transformation through industrial and energy restructuring; resource-based cities like those in Shanxi succeeded by shifting development paradigms, enhancing policy frameworks, and optimizing energy consumption, offering replicable solutions for overcoming resource-environmental constraints.

Keywords

Cities, low-carbon economy, concept, typical models

1. Introduction and Literature Review

Urban low-carbon economy refers to an economic development model within urban areas that achieves decoupling between economic growth and carbon emissions through technological innovation, institutional innovation, industrial restructuring, and other means. Its core lies in improving energy efficiency, reducing greenhouse gas emissions, while simultaneously promoting sustainable economic development. With the intensification of global climate change and increasing pressure on resources and the environment, research and development concerning the urban low-carbon economy have garnered widespread attention.

In theoretical research, scholars have conducted in-depth explorations of the urban low-carbon economy from various perspectives. YANG Ling et al. (2025), through empirical research, found that low-carbon city pilot policies significantly promote urban Green Total Factor Productivity (GTFP), with regional heterogeneity observed. Industrial structure upgrading played a mediating role in this process, while technological innovation and industrial agglomeration exerted a moderating and facilitating effect. LI Zongze et al. (2025) utilized CiteSpace software to conduct a bibliometric analysis of the literature in the field of green and low-carbon development. Their analysis revealed the evolution of research hotspots: from early explorations of "low-carbon economy" and "green economy" theories, to a mid-term focus on "carbon emissions" and "ecological civilization" policy practices, and more recently, deepening pathways centered around the "dual carbon" (carbon peak and carbon neutrality) goals.

In practical research, many cities have begun actively exploring low-carbon development models. ZHENG Ming et al. (2025), studying the key design points for high-rise buildings in the context of a low-carbon economy, proposed that optimizing the building shape coefficient and improving the thermal resistance of the building envelope can effectively reduce building energy consumption, achieving energy saving and emission reduction. MIAO Changqing (2025), from the perspective of the real estate economy, explored the green transformation and low-carbon development pathways of the real estate sector in building ecologically livable cities, emphasizing the importance of measures such as promoting green buildings and applying renewable energy.

The development pathways for an urban low-carbon economy can be explored from aspects such as policy guidance and institutional innovation, technological innovation and industrial upgrading, and public participation and awareness enhancement. Governments should formulate and improve relevant policies and regulations, strengthening guidance and support for low-carbon economic development. For instance, ZHOU Guangxiu et al. (2025) pointed out that policy systems and institutional mechanisms are the guarantee for new quality productive forces to empower low-carbon economic development in Northeast China, advocating for increased policy guidance and ensuring effective

policy implementation.

Technological innovation is a key driver for advancing the urban low-carbon economy. Cities should increase investment in low-carbon technology R&D, encourage enterprises to engage in green technology innovation, actively foster emerging industries, and optimize the industrial structure. LIU Xuemin (2025), researching urban landscaping construction in Xuzhou City, proposed strategies utilizing modern technological means to improve landscaping management, achieving resource optimization and low-carbon development.

Furthermore, public participation and awareness enhancement are crucial safeguards for the development of the urban low-carbon economy. Through publicity and education, public understanding and recognition of the low-carbon economy can be increased, guiding residents towards adopting low-carbon lifestyles. ZHOU Guangxiu et al. (2025) emphasized that promoting low-carbon lifestyles is a vital safeguard for advancing the low-carbon economy. They suggested leveraging diverse channels to disseminate knowledge about low-carbon living and enhance residents' awareness of energy saving and emission reduction.

In the future, with the development of new quality productive forces and continuous advancements in technological innovation, the urban low-carbon economy will face more opportunities and challenges. We anticipate that further research findings will provide theoretical support and practical guidance for the development of the urban low-carbon economy, collectively promoting the green transition and sustainable development of cities.

2. Concept and Connotation of Low-Carbon Economy

The concept of a low-carbon economy, first introduced in the 2003 UK Energy White Paper Our Energy Future: Creating a Low-Carbon Economy, has since garnered extensive global attention and in-depth research. Its core essence lies in minimizing the consumption of high-carbon energy sources such as coal and petroleum, reducing greenhouse gas emissions, and achieving a win-win scenario for socioeconomic development and ecological environmental protection through technological innovation, institutional innovation, industrial restructuring, new energy development, and other means. Within the context of urban development, the low-carbon economy provides a novel model and pathway for sustainable urban growth. As cities serve as hubs for economic activities and population concentration, their energy consumption and carbon emissions account for a disproportionately high share of global totals. Thus, developing a low-carbon economy holds immense significance. Liu Chunling (2011) noted that the low-carbon economy represents a new economic development model, consistent with the principles of sustainable development and the vision of a resource-efficient, environmentally friendly society. It is closely linked to ongoing efforts in energy conservation, emission reduction, and the circular economy. This transformation in economic development is not merely a superficial adjustment to the traditional high-carbon model but rather a profound systemic shift involving multiple dimensions, including production, consumption, technology, and institutions.

The connotation of the low-carbon economy is rich and multifaceted, encompassing key elements across several levels. At its core, it aims to decouple economic growth from carbon emissions—ensuring sustained economic expansion while significantly reducing carbon emissions per unit of output through technological and institutional innovations. This necessitates deep-seated transformations in urban industrial structures, energy utilization, transportation systems, and more. Zhang Ping et al. (2011) further elaborated: "The low-carbon economy not only addresses resource utilization but also fundamentally engages with issues of equity, justice, democracy, and a reorientation of human values." This indicates that the low-carbon economy transcends technological innovation, embodying a new development philosophy and model that requires a reexamination of the relationship between humans and nature, as well as among individuals in society. For instance, urban planning should prioritize reducing residents' commuting distances to lower transportation-related carbon emissions. In industrial layout, cities should encourage the development of high-tech industries with low carbon footprints while phasing out traditional sectors characterized by high pollution and energy intensity. Such transitions demand collaborative efforts from governments, enterprises, residents, and other stakeholders.

Technological and institutional innovations serve as two critical drivers in realizing a low-carbon economy. In technological innovation, the development and application of new energy technologies—such as large-scale utilization of renewable sources like solar, wind, and hydro power—alongside advancements in energy efficiency, carbon capture, and storage technologies, provide essential support for reducing carbon emissions. Taking solar energy as an example, Xiang Yuhong et al. (2014) highlighted that as technology matures and costs decline, solar photovoltaic systems are increasingly deployed in urban settings. These systems not only power large public buildings but also supply clean energy to residential structures, effectively reducing reliance on traditional fossil fuels. Institutional innovation manifests in policy guidance, legal frameworks, and market mechanisms. For instance, the establishment of carbon trading markets incentivizes enterprises to reduce emissions through market-based approaches, optimizing resource allocation. At the urban level, such innovations must be adapted to local contexts—for example, integrating low-carbon principles into urban planning to foster green buildings and intelligent transportation systems. Municipal governments can formulate localized low-carbon development plans, establish dedicated funding mechanisms to encourage technological innovation and emission reduction, and strengthen environmental oversight of high-energy-consumption, high-emission projects to ensure effective implementation of low-carbon goals.

The low-carbon economy shares close connections with concepts like the circular economy, green economy, and ecological economy, yet it also exhibits distinct characteristics. While these paradigms share common theoretical foundations, technical approaches, and objectives—emphasizing environmental friendliness, resource efficiency, emission reduction, and ecological balance—the low-carbon economy uniquely prioritizes carbon emission constraints, focusing sharply on climate

change mitigation. In urban development, this requires cities to build upon resource recycling and ecological conservation by further targeting greenhouse gas reductions. Strategies include constructing low-carbon energy systems and promoting industrial decarbonization to achieve sustainable urban growth. As Xiang Yuhong et al. (2014) articulated, the core principles of the low-carbon economy encompass environmental protection and low-carbon practices, further distilled into the "three lows and three highs": low energy consumption, low emissions, low pollution, high efficiency, high effectiveness, and high productivity. These principles are vividly reflected in urban low-carbon initiatives. In transportation, promoting new energy vehicles, optimizing public transit systems, and encouraging walking and cycling not only reduce emissions but also enhance transport efficiency, improve air quality, and create healthier, more livable urban environments.

In practical research on urban low-carbon economies, it is essential to delve into development models, influencing factors, and challenges at the city level. On one hand, optimizing and upgrading urban industrial structures represents a critical pathway. This involves developing low-carbon industries like high-tech sectors and modern services to gradually replace traditional high-emission, energy-intensive industries. For example, Cheng Quanguo et al. (2013) observed that many cities have established high-tech industrial parks to attract low-carbon enterprises, thereby enhancing industrial competitiveness while reducing urban carbon intensity. On the other hand, restructuring urban energy consumption is equally vital, requiring an increased share of clean energy and improved energy efficiency. In the construction sector, adopting green building standards, energy-saving materials, and technologies can significantly reduce operational energy use and emissions. Simultaneously, urban low-carbon development is influenced by a confluence of factors—policy, technology, market dynamics—necessitating comprehensive systemic analysis. As Zhou Langsheng et al. (2011) emphasized, advancing the low-carbon economy entails innovations in production technology, social institutions, and developmental perspectives, alongside transformative shifts in production modes, lifestyles, and values. Therefore, cities pursuing this path must not only focus on technological and industrial transitions but also strengthen public awareness, advocate for low-carbon lifestyles, and foster broad societal participation to collectively drive progress.

3. Representative Models

As hubs of economic activity and population concentration, cities are pivotal for achieving low-carbon development. Different cities have explored distinctive low-carbon economic development models based on their socioeconomic characteristics and resource endowments, offering valuable practical experiences and theoretical insights for global urban low-carbon transitions.

Wuhan City, a key central city in central China, has undertaken comprehensive and in-depth explorations in low-carbon economic development. ZHU Yi (2023) systematically analyzed Wuhan’s low-carbon development trajectory, revealing that the city established a robust theoretical foundation and methodological framework to clarify the essence of low-carbon economy. Integrating theories of

sustainable development, environmental Kuznets curve, and environmental externalities, Wuhan built solid theoretical underpinnings for its initiatives. The study noted that during 2009–2020, population growth, economic expansion, and energy structure positively contributed to increased carbon emissions, while energy consumption intensity exerted a negative moderating effect. Consequently, Wuhan proposed policy recommendations at macro and micro levels, covering key areas such as promoting low-carbon retrofitting in energy-intensive industries, scaling up low-carbon industries, optimizing the energy mix, and refining carbon emission trading markets. For instance, Wuhan advanced technological upgrades in traditional sectors like steel and petrochemicals, reducing carbon emissions per unit output through energy-saving technologies. Simultaneously, it actively fostered emerging low-carbon industries like new energy vehicles and energy-efficient equipment manufacturing, elevating their share in the economic structure. In energy optimization, Wuhan progressively reduced reliance on coal while increasing the supply of clean energy sources such as natural gas, wind, and solar power. Policy guidance and market mechanisms further accelerated the green transformation of energy consumption. Through these multidimensional synergies, Wuhan effectively curbed carbon emission growth while sustaining healthy economic development, offering replicable models for similar cities.

Developed nations have pioneered low-carbon economic development, setting global benchmarks through diversified policy instruments and technological innovation. The United Kingdom, as highlighted by SUN Quansheng (2023), proposed the low-carbon model early on. By enacting stringent climate legislation, implementing energy taxes, and establishing carbon trading systems, the UK significantly reduced emissions. Its Climate Change Act institutionalized carbon budgeting, embedding emission reduction targets into a legally binding framework. Carbon markets provided economic incentives for corporate decarbonization, driving innovation and operational optimization. Concurrently, substantial government funding supported R&D in renewable energy, energy efficiency, and carbon capture technologies, accelerating commercial deployment. Japan, meanwhile, prioritized policy-driven and technology-enabled low-carbon societal transformation. The government enforced rigorous energy efficiency standards, promoted energy-saving products and green buildings, and enhanced energy utilization. In transportation, Japan advanced electric and hybrid vehicles while expanding charging infrastructure to encourage low-carbon mobility. Renewable energy, particularly solar and wind, received policy subsidies and market incentives for widespread adoption. Germany centered its approach on Energiewende (energy transition), reducing fossil fuel dependence and scaling up renewables. The Renewable Energy Act provided legal safeguards and economic incentives for wind and solar power, catalyzing rapid industry growth. Industrial decarbonization was pursued through strict energy-saving measures, green manufacturing, and circular economy models. These cases demonstrate that diversified policies and sustained innovation are critical drivers of low-carbon transitions, offering universal lessons for cities worldwide.

Langfang City, leveraging its strategic location, actively integrated into the Beijing-Tianjin-Hebei coordinated development strategy while pioneering low-carbon initiatives. ZHAO Hongliang (2018)

emphasized that Langfang tailored its approach to local industrial foundations and resource endowments. By optimizing industrial and energy structures, the city achieved low-carbon economic transformation. On one hand, Langfang rejected energy-intensive and polluting industrial projects, instead upgrading traditional sectors and nurturing emerging industries like electronics, new energy, and high-end equipment manufacturing. This fostered a technology-led low-carbon industrial system. For example, in electronics, it attracted advanced chip manufacturing and software R&D firms, enhancing technical capabilities and value addition while lowering carbon intensity. On the other hand, Langfang expanded modern services by developing financial and cultural innovation hubs, deepening integration between services and manufacturing to reduce overall carbon intensity. Energy restructuring involved scaling up natural gas and solar power while reducing coal dependence. Cross-regional energy collaboration with Beijing and Tianjin further diversified clean energy supplies. Policy support—including fiscal subsidies, tax incentives, and green credit—created an enabling environment. Through these measures, Langfang balanced rapid growth with emission control, charting a context-specific low-carbon pathway.

Resource-based cities face dual challenges of resource depletion and environmental pressure, making tailored low-carbon models essential for sustainability. YUAN Yingqi (2020) argued that such cities must transform development paradigms, strengthen policy frameworks, establish innovation platforms, optimize energy consumption, adjust industrial structures, and cultivate low-carbon markets. Shanxi Province, a major coal-producing region in China, exemplifies this transition. Long dependent on coal, Shanxi grappled with high emissions and pollution. Recent reforms included coal resource tax adjustments, green mining technology systems, and clean coal utilization programs—enhancing efficiency while cutting emissions. Concurrently, the province accelerated renewable energy projects like wind and solar power to diversify its energy mix. Industrially, it upgraded coal and power sectors while developing high-end manufacturing, new materials, and cultural tourism to reduce carbon-intensive industries' dominance. Enhanced innovation capacity—through research funding, talent recruitment, and industry-academia-research collaboration—further advanced low-carbon technologies. These efforts demonstrate how resource-based cities can overcome environmental constraints through innovation-driven transformation, achieving synergistic economic and ecological progress.

4. Results and Outlook

The urban low-carbon economy represents a novel economic development model centered on decoupling economic growth from carbon emissions. It emphasizes the integrated application of multiple approaches, including technological innovation, institutional innovation, and industrial restructuring. This model prioritizes not only sustained economic growth but also significant reductions in carbon emissions per unit output through technological and institutional advancements, thereby achieving a win-win scenario for socioeconomic development and ecological conservation. Throughout

this process, three critical pathways emerge: policy guidance and institutional innovation, technological innovation and industrial upgrading, and public participation and awareness enhancement. Governments provide clear direction and incentives through policies such as carbon emission standards and energy-saving subsidies. Technological innovation serves as the core driver—advancements in renewable energy, energy efficiency, carbon capture, and storage technologies bolster the optimization of urban energy structures and industrial decarbonization. Concurrently, public engagement and awareness are indispensable; publicity and education foster low-carbon lifestyles, cultivating a supportive social environment for urban low-carbon development.

From a practical perspective, diverse cities have developed distinctive low-carbon models tailored to their socioeconomic characteristics and resource endowments. Wuhan City established a robust theoretical foundation by defining the essence of low-carbon economy through frameworks integrating sustainable development theories. The city proposed policies promoting low-carbon retrofitting in energy-intensive industries, scaling up low-carbon sectors, optimizing energy mixes, and refining carbon trading mechanisms. These measures effectively controlled emission growth while sustaining healthy economic progress. Langfang City, leveraging its geographic advantages within the Beijing-Tianjin-Hebei coordinated development strategy, achieved low-carbon transition through industrial and energy restructuring, offering a replicable blueprint. Resource-based regions like Shanxi Province exemplified transformative pathways—shifting development paradigms, strengthening policy frameworks, and diversifying energy consumption—providing invaluable insights for similar cities grappling with resource and environmental constraints.

Future Prospects：

The urban low-carbon economy holds vast potential, with technological innovation poised to lead transformative changes: Renewable energy technologies will achieve breakthroughs, expanding the application of solar, wind, and hydro power. Declining costs and enhanced efficiency will elevate renewables to a dominant role in urban energy supply. Carbon capture and storage (CCS) technologies will see broader adoption, supporting emission reductions in industrial processes. Smart energy management systems, powered by IoT, big data, and AI, will optimize energy allocation, invigorating low-carbon buildings and transportation. Institutional innovation will provide critical safeguards: Carbon trading markets will mature through optimized rules and expanded coverage, incentivizing corporate emission reductions and technological innovation. Green finance systems will deepen, offering diversified funding instruments for low-carbon R&D and clean energy projects. Cross-departmental governance mechanisms will strengthen policy coordination, planning synergy, and regulatory oversight. Public participation will shape new norms for low-carbon development: Rising low-carbon consumer markets will drive corporate investment in green products, creating a "demand-pull-supply, supply-stimulates-demand" virtuous cycle. Routine low-carbon actions—such as green commuting, energy conservation, and waste sorting—will become deeply ingrained. Citizens will actively engage in climate initiatives via social media and volunteer platforms while monitoring

corporate and governmental accountability. Enhanced education and training will cultivate professionals with low-carbon expertise, providing intellectual support for urban transitions. Moving forward, the synergy of technological advances, institutional reforms, and civic engagement will propel urban low-carbon economies to new heights. We anticipate accelerated translation of research into practice, empowering cities to achieve advanced green transitions and sustainable development. Together, urban centers will contribute decisively to global climate action, forging a cleaner, more prosperous, and livable future for all.

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