Dean&Francis

ISSN 2959-6130

A Review of the Synergistic Mechanism between Green Low-Carbon City Construction and Industrial Structure Adjustment

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Abstract:

With the intensification of global warming challenges, people have begun to pay attention to how to build low-carbon cities and the adjustment and transformation of industrial structures. However, existing research lacks systematic analysis of the synergistic mechanisms between these two aspects. This study conducts a systematic analysis through a policy-technology-society tri-dimensional framework, examining the coordination between policy and innovation, the synergy between cities and industries, and drawing on global experiences to focus on the gradual transition pathways of industrial transformation in developing countries. This study provides a theoretical basis for low-carbon city construction and industrial restructuring. Building low-carbon cities requires systematic coupling of policy guidance, technological innovation, and social participation. Policies serve as the fundamental guarantee, requiring strengthened institutional frameworks and market incentives. Technological synergy acts as the core driver, demanding breakthroughs in cost reduction and high-carbon effect mitigation. Social collaboration forms the implementation foundation, needing enhanced public participation and equitable transition mechanisms. Future research could compare capacity, efficiency, and cost changes during the transition from traditional chemical industries to new energy sectors, identifying renewable energy types with minimal production losses.

Keywords: Green and low-carbon cities; Industrial collaborative transformation; Policy instruments.

ISSN 2959-6130

1. Introduction

Global warming has always been one of the most phenomenal issues of concern to all sectors of society at China and abroad. As early as 1988, the United Nations Intergovernmental Panel on Climate Change (IPCC) pointed out in its Fourth Global Climate Assessment Report, released in 2007, that the main cause of climate warming is "anthropogenic influence" At the 2007 Davos conference, global warming surpassed terrorism and regional conflicts as the world's most pressing issue [1]. In recent years, the Chinese government has transitioned from supporting the development of traditional fuel vehicles to vigorously supporting new energy vehicles. This transition includes improving vehicle hardware standards, strengthening infrastructure, and improving support and security conditions. The government has also implemented policies that exempt new energy vehicles from purchase taxes and provide direct subsidies to support the supply side. Some of the world's major countries have implemented various measures in this regard. For example, Germany subsidizes relevant industries through an energy tax, the United States strengthens intellectual property rights to promote the development of the new energy industry, and the Japanese government provides subsidies for new energy vehicle purchases and has built 4,700 large-scale charging facilities [2]. In summary, this paper aims to summarize the synergistic dimensions of the transition from the traditional chemical industry to the new energy industry in the context of building a low-carbon city and green economy. Then, it will analyze domestic and foreign cases, as well as the challenges and suggestions that China is facing in this field. The goal is to provide a theoretical basis for green, low-carbon, and sustainable development.

2. Core Concepts and Theoretical Foundations

2.1 Green and Low-carbon City

The core concept of green low-carbon cities is to achieve sustainable urban development through optimizing energy structures, improving resource utilization efficiency, and enhancing ecological resilience, with the goals of low energy consumption, low pollution, and low emissions. The visionary concept of green low-carbon cities first emerged from Britain in the dawn of the 21st century, sparking a global movement that continues to reshape the urban landscapes. At its heart lies a profound truth - that by revolutionizing the energy systems, maximizing every resource, and slashing carbon footprints, people can finally harmonize economic progress with social wellbeing and environmental stewardship [3]. The European Green Deal initially outlines the pathways for policy implementation, covering the energy sector, industrial sector, construction sector, transportation sector, and food sector [4]. The evaluation indicators for green low-carbon cities comprise six dimensions: economic decarbonization, low-carbon infrastructure, low-carbon lifestyles, low-carbon technology development, improvement of low-carbon institutions, and superior ecological environments [5].

2.2 Theoretical Basis of Collaboration

The UN assessment report warns humanity that neglecting environmental protection will accelerate global warming. The optimal solution lies in building low-carbon cities and implementing sustainable development strategies through collective global efforts. Many nations and cities have taken their first step by establishing urban forests [6]. Crucially, low-carbon urban development requires synergistic city-industry interaction. For instance, green industries (e.g., new energy vehicles) can reduce transportation emissions, while urban policies (like charging station subsidies) stimulate industrial demand. However, negative conflicts must be addressed – cities restricting emissions without providing industrial alternatives may trigger economic downturns. Simultaneously, people must internalize externalities: making polluters pay and rewarding environmental stewards.

3. Key Dimensions of Collaboration

The synergistic mechanism between green low-carbon city development and industrial restructuring constitutes a pivotal pathway to achieving sustainable development. Through multidimensional interactions—including policy safeguards, technological innovation, and social collaboration—this approach fosters the co-evolution of economic transformation and ecological benefits.

3.1 Policy Coordination

Policy synergy serves as the foundational safeguard for green low-carbon city development and industrial restructuring. Through legislative frameworks, economic incentives, and administrative oversight, it guides market transformation while reducing transitional resistance across industries. A prime example is the European Union's sequential introduction of the European Green Deal and Carbon Border Adjustment Mechanism (CBAM), CBAM ties industrial policies to urban low-carbon goals by increasing the cost of carbon emissions domestically, incentivizing enterprises to adopt new energy sources, while imposing taxes on imported high-carbon products (covering six sectors: steel, aluminum, cement, fertilizers, electricity, and hydrogen) to reduce carbon-intensive imports. The EU CBAM has maintained consistent coverage for fertilizers and electricity across all legislative proposals, while progressively expanding its scope to include additional sectors such as iron/steel, aluminum, and hydrogen throughout the legislative process, ultimately resulting in the final legislation adopting the most comprehensive sectoral coverage to date [7]. Within China's sustainable development framework, the country has established a robust legal system centered on the "Dual Carbon" goals (carbon peaking by 2030 and carbon neutrality by 2060), including the Environmental Protection Law, Climate Change Response Law, and the "1+N" policy framework, while implementing economic incentives like extended purchase tax exemptions for new energy vehicles (2023-2027) and 15% corporate income tax reductions for photovoltaic enterprises to facilitate low-carbon industrial transition. However, despite launching a national carbon market, China continues to face policy coordination challenges as some provinces relax restrictions on high-carbon industries to maintain GDP growth, creating counterproductive outcomes that hinder decarbonization progress.

3.2 Technical Collaboration

Technological collaboration is the core engine of the low-carbon transformation. It encompasses both industrial production technological innovation and the upgrading of urban low-carbon infrastructure, and the two complement each other. At its core, this approach leverages cross-sectoral technological innovation and systemic integration to dismantle the carbon-intensive legacy of traditional industries, establishing a green, low-carbon and circular development model [8,9]. In industrial production, renewable energy is fundamentally restructuring manufacturing's carbon emission profiles - for instance, substituting fossil fuels with green hydrogen in chemical processes can reduce lifecycle carbon emissions by over 70%, as demonstrated by China Petroleum's Xinjiang solar-to-hydrogen project which achieves annual CO_2 reductions of 480,000 metric tons [10,11]. At the same time, the popularization of circular economy technology has led to an improvement in resource utilization efficiency. For example, the recycling technology for power batteries has achieved a high recovery rate (for key metals such as lithium, cobalt, and nickel), effectively alleviating the reliance of the new energy industry on non-renewable resources [12]. In the urban system, the integration of digital technology and energy infrastructure has produced new low-carbon solutions. The smart grid dynamically adjusts the electricity load through the demand-side response mechanism. The virtual power plant project built in Shanghai has aggregated over 500 megawatts of adjustable load, equivalent to reducing the need for the construction of a medium-sized coal-fired power plant. Building-integrated photovoltaics (BIPV) technology enables urban structures to transform from energy consumers into energy producers. The Shenzhen Future Building project meets 30% of its electricity demand through curtain-wall photovoltaic systems [13,14].

3.3 Social Collaboration

Social collaboration forms the very bedrock for bringing policies and technologies to life, uniting businesses, communities, and individuals in a shared mission toward low-carbon transformation.

In people's daily lives, each of people holds the power to make a difference—through simple yet meaningful actions like waste sorting, choosing public transport, and embracing greener ways to move.

In the corporate world, industry self-regulation is taking root – over 2,000 companies globally have pledged carbon neutrality timelines through the *Science Based Targets initiative (SBTi)*, while tech giants like Apple mandate 100% renewable energy adoption from suppliers by 2030, creating powerful ripple effects for transformation. Yet challenges persist: premium pricing for organic foods and new energy vehicles leaves low-income groups behind, coupled with lingering knowledge gaps in some communities. This calls for targeted subsidies to cushion vulnerable populations while intensifying climate literacy programs that leave no one behind in the green transition.

4. Case Studies of Traditional Chemical Transformation

4.1 The Transformation of the Traditional Chemical Industry into the New Energy Industry in Some Regions of China

Since the President of China made the scientific assertion that "green water and green mountains are golden mountains," China has incorporated the goal of "dual carbon" into its national strategy. The country believes that constructing green and low-carbon cities is a core path to promoting sustainable development. In recent years, some regions in China have used the municipal or district level as a pilot area to explore ways of transforming traditional chemical industries into green, new energy industries. For instance, PetroChina has constructed multiple centralized photovoltaic power generation projects in oilfields and chemical plants in Xinjiang and Gansu. The Ningxia Coal Company is currently developing a 4 million tons per year coal-to-oil project at the Ningdong Energy Chemical Base. Furthermore, the company has announced its intention to construct 2 million kilowatts of composite photovoltaic bases surrounding its facilities by the year 2023, with a projected investment exceeding 10 billion yuan [15]. Or-

ISSN 2959-6130

dos City has abundant coal reserves, and it has recently adopted the concept of ecological priority and green development. The city has also implemented initiatives to promote energy-saving production, low-carbon living, and ecological green development. In the transformation and upgrading of traditional coal power projects, the following measures are promoted: a gradual transformation of coal power from the main power source to a supportive and regulating power source; comprehensive implementation of energy-saving and consumption-reducing renovation; orderly elimination of backward coal power production capacity; and exploration of the demonstration of carbon reduction of CCUS (Carbon Capture, Utilization, and Sequestration Technology) for coal power units. Moreover, in recent years, financial institutions in Erdos have strongly supported the green and low-carbon transformation of the traditional chemical industry, as well as the construction of new energy power systems, by issuing green loans. As of the end of June 2024, the balance of green loans for the electricity, heat production, and supply industry was RMB 28.66 billion. This accounted for 34.8% of the total green loan balance, representing a 60.7% year-on-year growth and an increase of RMB 7.12 billion since the beginning of the year [16].

4.2 Cases of the Development of New Energy Technologies in Several European Countries and Japan

Many countries around the world have accumulated extensive experience in transforming traditional chemical industries. Governments are actively establishing sound policies and regulations. For example, the United Kingdom adopted <The Climate Change Act> and <The Low Carbon Transformation Plan>, which set statutory targets for reducing greenhouse gas emissions and promoting low-carbon transformation. On a social level, the United Kingdom is actively fostering public awareness, education, and promotion. It is also guiding community building and civic participation. The country disseminates low-carbon information through public service announcements and school textbooks. It calls for changes in public lifestyles and encourages community residents to participate in low-carbon projects and build low-carbon communities. Denmark, Germany, and Japan are leading the world in energy technology innovation by increasing investment in research and development of new energy sources, such as wind, solar, and hydrogen energy. They are also strengthening infrastructure construction and promoting its application [17]. These international cases provide many reference values for transforming China's traditional chemical industry.

5. Challenges and Suggestions for the Development of Low-Carbon Cities in China

5.1 Challenges

The lack of clarity in the subsidy policy for some new energy industries may cause enterprises or individuals to aim solely to embezzle subsidies rather than contribute to popularizing new energy development. There are no evaluation criteria for individual low-carbon demonstration standard projects, and the technologies and specifications are not uniform. The general public does not pay enough attention to green transportation, low-carbon travel, or reducing carbon emissions. People often shirk their responsibilities. Currently, the construction of low-carbon cities relies heavily on government promotion and lacks public and market support. Additionally, the public's understanding of low-carbon development is limited or misunderstood.

5.2 Suggestions

The central government should improve the energy conservation and carbon emission control policy system and clarify the objectives and policy measures for developing low-carbon cities. Local governments should strengthen financial and tax policy support, improve the carbon tax system, and conduct regular audits and assessments to ensure policies are implemented effectively. To avoid differences in standards between different cities or regions, relevant departments should implement standardized assessment and management. The government and banks should actively cooperate to improve the green financial system. They should also guide financial institutions to participate in green financial business and collaborate with enterprises, universities, and scientific research institutions to conduct green technology research and innovation. Strengthening international exchanges and cooperation is also necessary to share the fruits of technological innovation. On a social level, it is important to raise awareness and educate the public about low-carbon consumption and the concept and goals of low-carbon cities. If possible, the Ministry of Education should incorporate low-carbon development and green construction concepts into school textbooks to cultivate environmental protection awareness from an early age.

6. Conclusion

This essay discusses the concept of a green, low-carbon city, which is an urban development model that aims to reduce energy consumption, pollution, and emissions. This model seeks to promote the coordinated development of the economy, society, and environment by optimizing energy structures, improving resource utilization efficiency, and enhancing ecological resilience. The evaluation index system covers six aspects: the economy, infrastructure, and lifestyle decarbonization, the development of low-carbon technology, the improvement of the low-carbon system, and an excellent ecological environment. In the process of building a green, low-carbon city, the city and industry must develop synergistically. In the policy dimension, it promotes market transformation and reduces resistance to industrial transformation through laws, regulations, economic incentives, and administrative supervision. In the technological dimension, it breaks the high-carbon effect of traditional industries and builds a green, low-carbon development model through technological innovation and infrastructure upgrading. In society, it mobilizes enterprises, communities, and individuals to actively participate in low-carbon transformation and form a synergy. These three main dimensions can achieve low-carbon environmental protection and stimulate industrial demand through multifaceted cross-sectoral synergies. At the same time, care should be taken to avoid negative conflicts and implement the internalization of externalities, ensuring that those who damage the environment bear some of the costs and creating environmental incentives. Secondly, a series of case studies on the development of new energy in China, Japan, and some European countries has reinforced the need to establish green, low-carbon cities and restructure industries. These studies have also led to challenges and recommendations for China to improve its development of low-carbon cities. In the future, a comparative study can be conducted on capacity, efficiency, and cost changes in the transition from the traditional chemical industry to the new energy industry. This study could identify the type of new energy that minimizes capacity loss.

Authors Contribution
All the authors contributed equally and their names were listed in alphabetical order.

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