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# The Impact of Low-Carbon Pilot Policies on Urban Land Green Utilization

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**Abstract**

As global climate change becomes an increasingly urgent issue, low-carbon pilot policies have gradually been promoted worldwide as an important measure to address climate change. As a major area of resource consumption and carbon emissions, cities face the challenge of achieving green and sustainable development. This study analyzes the impact of low-carbon pilot policies on urban land green utilization, exploring their role in promoting the greening of urban land resources, reducing carbon emissions, and fostering sustainable development. Using a combination of quantitative and qualitative methods, and drawing on multiple case studies from typical cities, the study reveals the mechanisms through which low-carbon policies affect urban land use. The results show that low-carbon pilot policies significantly promote urban land green utilization, particularly in land development planning, land use efficiency, and ecological protection. This study provides theoretical support for further optimizing low-carbon policies and offers references for other cities' green development.

**Keywords:** low-carbon pilot policies, urban land use, green development, carbon emissions, land resources

## 1. Introduction

Low-carbon pilot policies have been gradually implemented in China since 2009 as a key strategy to address climate change and promote green low-carbon development. By selecting several cities as pilot areas, the government aims to optimize resource allocation, promote green transformation, and reduce greenhouse gas emissions. Low-carbon pilot cities explore suitable low-carbon development paths for China through policy guidance, technological innovation, and resource allocation. Figure 1 illustrates the distribution of low-carbon pilot policies across cities, showcasing different batches of pilot cities and reflecting the gradual promotion and demonstration effects of the policy. The low-carbon pilot policy has had a profound impact on land use, energy consumption, and carbon emissions, and has provided new opportunities for local economic transformation and green development. This study aims to analyze the impact of low-carbon pilot policies on urban land green utilization and provide references for future low-carbon urban development. To achieve the above objectives, this study combines qualitative and quantitative methods. First, the literature review section summarizes the research progress on low-carbon policies and urban land green utilization. Then, in the data analysis section, this study selects land use data from multiple typical low-carbon pilot cities, using statistical analysis and algorithm models to evaluate the implementation effects of the low-carbon policies. Finally, through case studies, the study explores the applicability and challenges of low-carbon policies in different urban contexts[1].

## 2. Related Research and Conceptual Introduction

### *2.1 Related Research on Low-Carbon Pilot Policies*

Since 2009, low-carbon pilot policies have been gradually implemented in China to promote green low-carbon development, optimize resource allocation, and reduce greenhouse gas emissions. The government has selected several cities as low-carbon pilots to explore low-carbon development paths through policy guidance and technological innovation. Figure 1 shows the distribution of China's low-carbon pilot policies, covering different batches of pilot cities from economically developed regions to less-developed areas. The first batch of pilot cities is concentrated in the more developed eastern coastal areas, such as Shanghai and Beijing, while the second and third batches expanded to the central and western regions, where low-carbon policies have promoted both green development and local economic transformation[2].

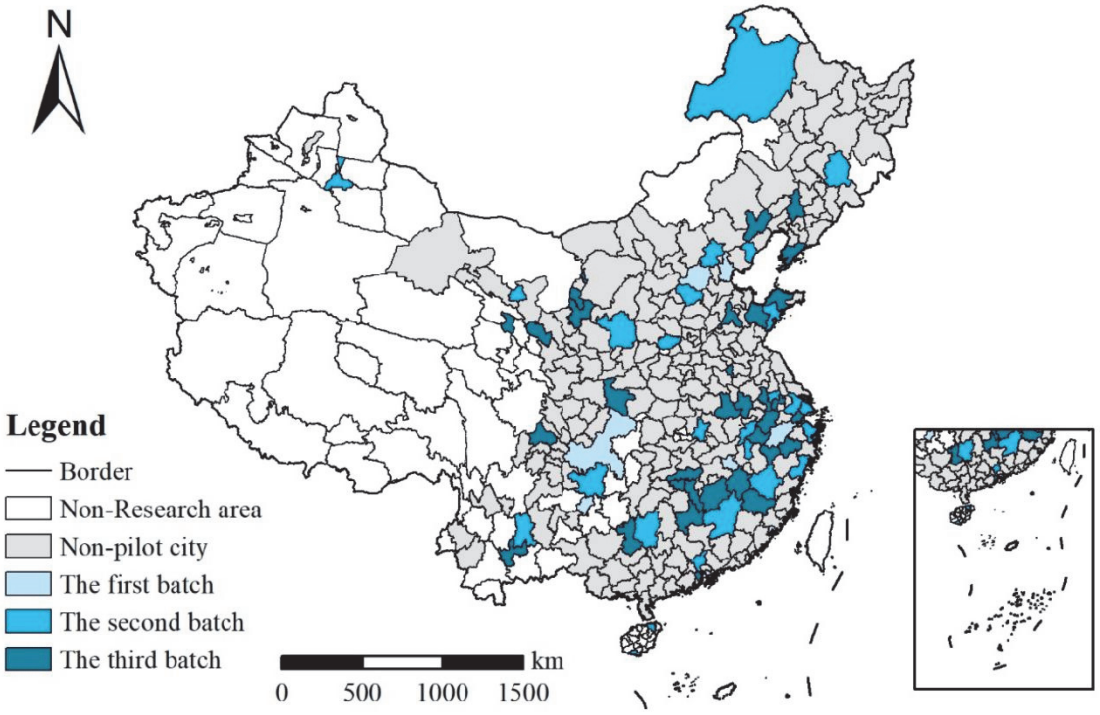


Figure 1. Distribution Map of Cities Implementing Low-Carbon Pilot Policies in China

According to existing research, low-carbon pilot policies have had a significant impact on urban land use. The policies have promoted the transformation of land green utilization patterns, optimized land resource allocation and usage, reduced carbon emissions, and improved land use efficiency. For example, some pilot cities have integrated green buildings, renewable energy, and green transportation into their planning, making land resources more efficient and environmentally friendly. Moreover, low-carbon policies have driven innovation in land development, green buildings, and energy conservation, promoting the integration of smart cities and green buildings to meet economic needs while reducing environmental burdens[3]. However, different batches of pilot cities face different challenges during implementation. Eastern regions benefit from advanced technologies and stronger execution capabilities, while central and western regions rely more on policy guidance and local innovation. Low-carbon pilot policies have also driven innovation and application of low-carbon technologies, particularly in fields such as low-carbon buildings, green energy, and smart transportation. These technologies not only reduce carbon emissions but also enhance urban environmental quality. In conclusion, the impact of low-carbon pilot policies on green land utilization is multifaceted, involving land development, resource use, and ecological protection. Figure 1 provides intuitive data support for analyzing the implementation effects of low-carbon policies in different regions and offers valuable experiences and policy recommendations for future low-carbon urban construction[4].

### *2.2 Definition and Development of Urban Land Use and Green Utilization*

Urban land use refers to the spatial allocation and utilization of land based on various social, economic, and environmental needs during the urbanization process. It involves the development, use, protection, and rational allocation of resources. As urbanization accelerates, traditional land use patterns face significant challenges, particularly with increasing resource scarcity and environmental pressures. Green land use has become an essential path to achieving sustainable urban development[5].

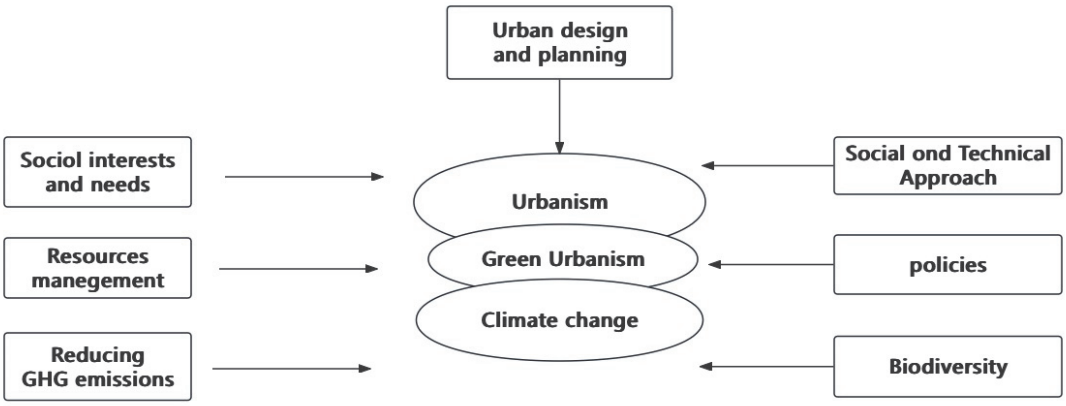


Figure 2. Green Urban Development Framework in Urban Design and Planning

Green land use refers to the consideration of ecological protection, resource conservation, and environmental friendliness in urban land planning and development, aiming to improve land use efficiency while reducing negative environmental impacts. This concept emphasizes the integration of green technologies, green infrastructure, energy efficiency, and ecological restoration into urban development to achieve green urban goals. The framework in Figure 2 shows the multidimensional elements of green urban development, including social interests and needs, resource management, greenhouse gas reduction, and climate change, and how these factors interact and overlap to collectively promote the construction of green cities. Specifically, green land use requires comprehensive consideration of various aspects of urban design and planning[6]. Social interests and needs form the foundation of land use planning, ensuring that urban land serves not only residential and economic development but also social equity and public welfare. Resource management plays a crucial role in green land use, requiring the rational allocation of natural resources, energy conservation, and prioritizing renewable resources to reduce environmental burdens. Reducing greenhouse gas emissions is a core objective of green urban development, achieved through measures such as green buildings and energy-efficient transportation to help address climate change. Climate change and biodiversity are two major challenges for green urban development. Climate change requires cities to focus on adaptability and disaster resilience in land use, promoting the construction of low-carbon cities. Biodiversity protection necessitates preserving ecological environments, creating green spaces, and restoring ecosystems during urban development to enhance urban ecological system functions and resilience.The framework in Figure 2 illustrates how these elements work together at various levels of urban design and planning, fostering the integration of green cities and land use. This approach combines social and technological methods, especially in the specific applications of urban planning and policy implementation, providing more effective paths for green urban development. It also highlights that green land use is not only a technical issue but a systemic, comprehensive social process that requires the participation of governments, enterprises, research institutions, and residents[7].Through this multidimensional green urban development framework, urban land use will move towards a more environmentally friendly, energy-efficient, and sustainable direction, facilitating the harmonious coexistence of ecology, society, and economy in the process of green transformation. Therefore, green land use is not only a necessary means to address climate change and resource shortages but also the foundation for building livable, smart, and green cities[8].

### *2.3 Mechanism of Low-Carbon Policies on Land Use*

The impact mechanism of low-carbon policies on urban land use is reflected in several aspects, including the optimization of land resource allocation, adjustment of land use structure, and promotion of green development models. Firstly, low-carbon policies have driven the efficient utilization of land resources. Under the guidance of low-carbon policies, urban land development has gradually shifted from traditional high-intensity development to low-carbon, energy-efficient, and sustainable models. This not only improves land use efficiency but also prevents excessive development from damaging the ecological environment. Secondly, low-carbon policies have optimized land use structures. Through policy incentives, low-carbon pilot cities place more emphasis on ecological protection and green construction in land planning, promoting projects related to green buildings, low-carbon transportation, and renewable energy. For example, some cities have established low-carbon zones or green building areas, prioritizing the use of limited land resources for environmental protection and ecological restoration, thus achieving the green transformation of land use. Moreover, low-carbon policies have driven the

transformation and upgrading of land use methods. In traditional urbanization, land was primarily used for industrial and residential development, neglecting the integration of environmental and ecological functions[9]. Low-carbon policies, however, emphasize ecological functions and environmental benefits, considering green infrastructure construction, urban green space expansion, and ecological corridor protection in land development. This policy direction ensures that land use not only considers economic benefits but also incorporates environmental and social benefits. In conclusion, low-carbon policies promote the green transformation of land use through multiple mechanisms, facilitating the optimization of land resource allocation and sustainable utilization. During this process, the formulation and implementation of policies, particularly the role of local governments, are key factors in achieving low-carbon goals.

## 3. Overview of Low-Carbon Pilot Policies

### *3.1 Objectives and Development of Low-Carbon Pilot Policies*

Low-carbon pilot policies are a key strategy for China to address climate change and promote green low-carbon development. Since 2009, the government has launched a series of low-carbon pilot cities, aiming to explore green transformation paths suited to China's national conditions through the implementation of low-carbon development models in selected regions, providing demonstrations and experiences for a nationwide low-carbon economic transition. The core goal of the low-carbon pilot policy is to reduce greenhouse gas emissions while promoting coordinated economic development and environmental protection. Specifically, the policy requires pilot cities to comprehensively plan and transform areas such as energy utilization, transportation, buildings, and industrial structures, aiming to minimize carbon emissions while maintaining economic growth through energy conservation, emission reduction, and clean energy promotion. The policy not only emphasizes direct emission reduction targets but also focuses on fostering low-carbon technologies, low-carbon industries, and low-carbon infrastructure, encouraging widespread recognition and participation in the green development concept.Furthermore, the low-carbon pilot policy has a demonstrative and radiating effect. By selecting typical cities as low-carbon pilots, the government hopes these cities can provide examples for others in terms of policy, technology, and management, helping promote nationwide low-carbon development. This top-down demonstration model has raised awareness of green development among local governments and has facilitated the spread and application of green technologies and industries. Throughout its development, the low-carbon pilot policy has undergone several stages, from the initial policy design and city selection to later-stage policy evaluation and experience summarization, gradually maturing. Currently, low-carbon pilot cities in China span across various regions, with targeted low-carbon development strategies tailored to the specific characteristics of each region. These pilot cities have made significant progress in energy, transportation, and building sectors, serving as active models for promoting green economies and low-carbon technology innovations. In summary, the low-carbon pilot policy's goal is to drive green low-carbon development by exploring suitable low-carbon development models for China, achieving energy conservation and emission reduction while promoting a win-win outcome for both the economy and the environment. As the policy progresses, the experiences and results from these pilots will provide valuable practical guidance for other regions' green transformation [10].

### *3.2 Domestic and International Low-Carbon Pilot Policy Cases*

Low-carbon pilot policies have been widely implemented globally, with many countries and regions exploring low-carbon economic transformation paths through pilot projects, accumulating rich experience. In China, the low-carbon pilot policy has been gradually rolled out since 2009, with multiple cities and regions becoming low-carbon pilots and achieving significant results. As the capital of China, Beijing has taken on the responsibility of leading low-carbon transformation. Through green building standards, the promotion of clean energy buses, and the establishment of a carbon emissions trading market, Beijing has provided valuable experience for low-carbon city construction. Shenzhen, with its focus on green technologies and low-carbon transportation, has become a leader in domestic low-carbon development by promoting electric buses and new energy taxis. Hangzhou, through optimizing its energy structure, increasing the use of renewable energy, and promoting low-carbon district construction, has achieved a green transformation in urban land use, offering a low-carbon development path for small and medium-sized cities. Internationally, many countries have also advanced green transformation through low-carbon pilot policies. Germany’s “Energy Transition” (Energiewende) policy has become one of the world’s most well-known low-carbon pilot projects. By promoting renewable energy applications, improving energy efficiency, and reforming the power market, Germany has achieved remarkable results in cities like Freiburg, advancing green urban development. In California, USA, the "Clean Energy and Climate Act" and a series of low-carbon policies have promoted low-carbon economic construction, with cities like Los Angeles and San Francisco significantly reducing carbon emissions through the application of new energy technologies and low-carbon transportation. In the UK, low-carbon policies have helped cities like London and Manchester reduce carbon

emissions through green buildings, low-carbon transportation, and carbon trading measures, offering valuable demonstrations for other cities. These domestic and international cases show that the successful implementation of low-carbon policies relies on effective government guidance and technological innovation. Through green technologies, energy structure adjustments, and low-carbon transportation, low-carbon pilot cities have not only reduced carbon emissions but have also provided valuable experience and guidance for the low-carbon transformation of other cities worldwide.

## 4. Data Analysis and Algorithm Models

### *4.1 Data Sources and Preprocessing*

The analysis of the implementation effects of low-carbon pilot policies relies on extensive urban land use data, energy consumption data, and carbon emission data. To accurately evaluate the impact of low-carbon policies, it is essential to obtain relevant data and preprocess it effectively. The data sources primarily include publicly released statistical data from the government, land use data provided by urban planning departments, carbon emission data from environmental protection agencies, and energy consumption data from third-party organizations.Specifically, land use data involves urban land types, usage intensity, and land use changes; energy consumption data includes the usage of various energy types such as electricity, natural gas, and coal; and carbon emission data covers greenhouse gas emissions generated by energy consumption, industrial activities, and transportation. These data help analyze the impact of low-carbon pilot policies on land resource utilization efficiency, energy structure optimization, and carbon emission levels. Data preprocessing is a crucial step in data analysis to clean, transform, and standardize raw data, ensuring its quality and consistency. First, missing values are handled by interpolation or deletion of incomplete samples. Second, data normalization and standardization are performed to eliminate discrepancies between different data scales, ensuring comparability. Data is also classified and grouped by city regions and time periods to allow for more precise analysis. Table 1 is a sample data table that shows changes in land use and energy consumption before and after the implementation of the low-carbon pilot policy in a certain city:

Table 1. Sample data

| Region | Land Use Type | Energy Consumption (GWh) | Carbon Emissions (tons) | Before Policy (2015) | After Policy (2020) | Change (%) |
|---|---|---|---|---|---|---|
| City Center | Commercial Area | 150 | 12.5 | 100 | 75 | -25% |
| City Center | Residential Area | 200 | 15.0 | 120 | 90 | -25% |
| Suburban Area | Industrial Area | 300 | 30.0 | 250 | 180 | -28% |
| Suburban Mixed | Mixed Development | 100 | 7.5 | 80 | 65 | -18.75% |

From the table, we can observe that the implementation of the low-carbon pilot policy has led to changes in land use and a significant reduction in energy consumption and carbon emissions. Energy consumption and carbon emissions have decreased across various regions, demonstrating the policy's positive effects on energy structure optimization and land resource utilization. Data preprocessing ensures more accurate analysis and provides strong support for evaluating the effects of the low-carbon pilot policy.

### *4.2 Spatial Analysis and Model Construction*

Spatial analysis plays a crucial role in the study of low-carbon pilot policies. By analyzing the spatial distribution of land use, carbon emissions, and energy consumption data in different regions, it helps reveal geographical changes following the implementation of low-carbon policies. The goal of spatial analysis is to identify differences in the effects of low-carbon policies across regions, explore the green development potential of different areas, and predict future impacts under various scenarios through model construction. To conduct effective spatial analysis, Spatial Autoregressive Models (SAR) and Geographically Weighted Regression (GWR) models are commonly used. These two methods are described below, along with their respective formulas. The SAR model is used to analyze the spatial correlation between carbon emissions, energy consumption, and land use changes in

different regions. The SAR model captures spatial dependence through spatial lag terms, meaning that carbon emissions in one region may be influenced by neighboring regions as shown in Formula 1:

$$y_i = \rho \sum_{j=i} w_{ij} y_j + \beta X_i + \epsilon_i$$

Where $y_i$ is the carbon emissions or energy consumption of region i; $w_{ij}$ is the spatial weight between regions i and j;$\rho$ is the spatial autoregressive coefficient, representing spatial dependence between neighboring regions;$\beta X_i$ is the independent variable for region i (e.g., land use type, policy implementation strength);$\epsilon_i$ is the error term.The SAR model is used to analyze regional differences in the implementation of low-carbon policies and to uncover the spatial effects of these policies.The GWR model is a method for performing local regression analysis in regions with strong spatial heterogeneity, and it is used to analyze the differential impact of low-carbon policies on land use and carbon emissions across various regions. GWR applies local regression models at different geographical locations to assess the degree of impact of low-carbon policies on each region. The basic formula 2 is:

$$y_i = \beta_0(u_i, v_i) + \beta_1(u_i, v_i)X_1 + \beta_2(u_i, v_i)X_2 + \cdots + \beta_k(u_i, v_i)X_k + \epsilon_i$$

Where $y_i$ is the carbon emissions or energy consumption of region i;$(u_i, v_i)$ is the spatial coordinate of region i;$\beta_k(u_i, v_i)$ is the local regression coefficient for the kk-th independent variable in region i;$X_k$ is the kk-th independent variable (e.g., land use type, policy strength);$\epsilon_i$ is the error term.Through the GWR model, we can analyze the local effects of low-carbon policies and uncover the heterogeneous effects across different regions.In the study of low-carbon pilot policies, SAR and GWR models help analyze and predict the spatial effects of low-carbon policies on land use, carbon emissions, and energy consumption. Spatial analysis can identify the low-carbon development potential of different regions, optimize policy measures, and provide data support for urban green transformation. For instance, to analyze the impact of low-carbon policies in city A, we first need to collect land use, energy consumption, and carbon emissions data from different regions of the city. Then, using the SAR model, we can evaluate the interregional influence on carbon emissions, while the GWR model will analyze the extent of the low-carbon policy's impact on different regions. This approach helps clearly understand which areas are most affected by the policy and which still face significant carbon emission pressures, providing guidance for future policy optimization. Overall, spatial analysis and model construction offer powerful tools for evaluating the effects of low-carbon pilot policies, aiding in the precise identification of policy impacts and optimizing future strategies.

*4.3 Data Analysis Results and Discussion*

In this section, we present the changes in land use, energy consumption, and carbon emissions across different regions before and after the implementation of the low-carbon pilot policy. By analyzing and comparing various data, we aim to provide a clearer understanding of the actual effects of the low-carbon policy and discuss the factors influencing its implementation. First, Figure 3 shows the changes in land use across different regions in a city before and after the policy implementation. The data indicates that the low-carbon policy has promoted the greening of urban land, especially with significant increases in green building proportions in industrial and residential areas.

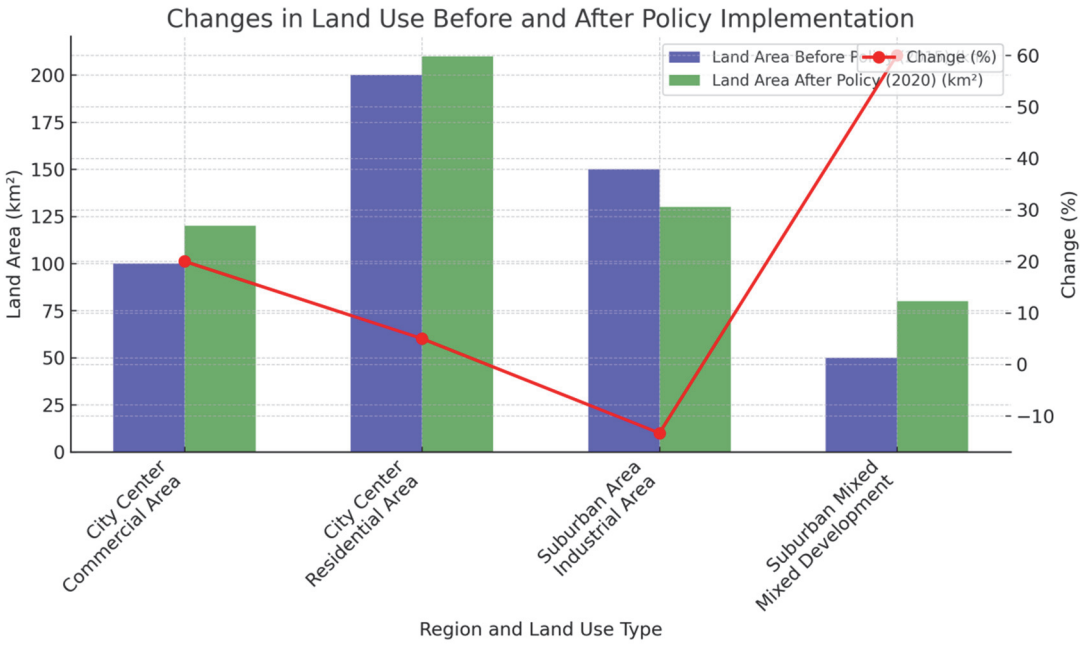


Figure 3. Changes in Land Use Before and After Policy Implementation

From the Figure 3, it is evident that after the implementation of the low-carbon policy, the land area of mixed development and commercial areas increased, indicating that the policy effectively promoted the transition to a sustainable urban development model. Notably, the land area of industrial zones decreased, reflecting the policy's success in driving industrial structure adjustments. Next, Figure 4 illustrates the changes in energy consumption across different regions. The analysis shows a significant reduction in energy consumption, particularly in industrial areas, where energy use efficiency greatly improved.

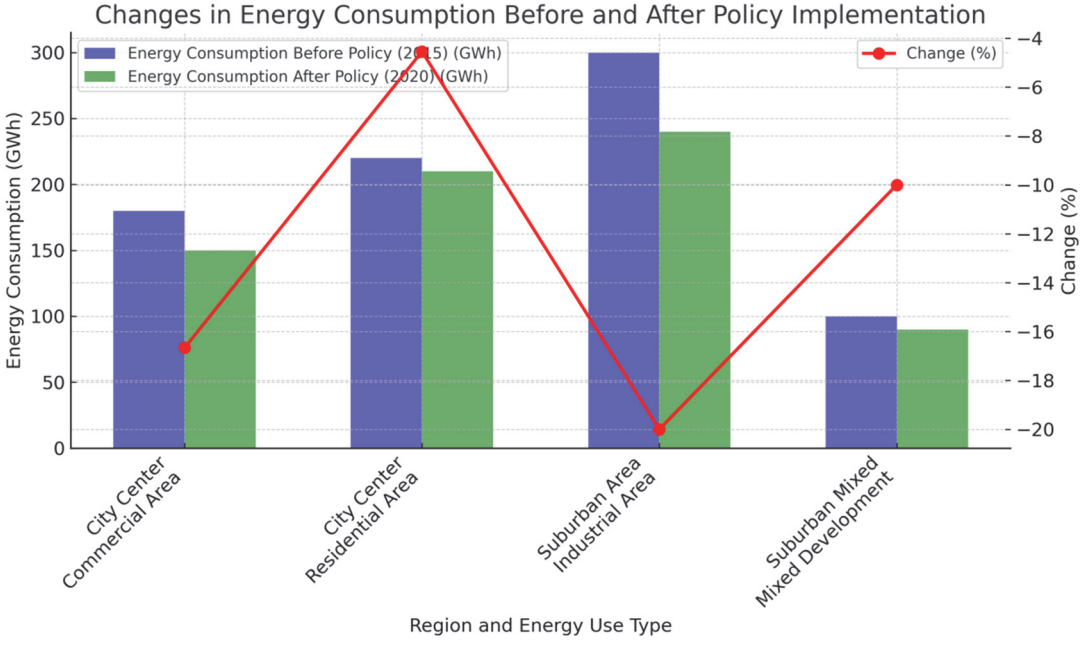


Figure 4. Changes in Energy Consumption Before and After Policy Implementation

The data from Figure 4 indicates the largest reduction in energy consumption occurred in the industrial areas, highlighting the low-carbon policy's significant effect on reducing energy consumption in high-energy industries. Additionally, energy consumption in commercial and residential areas also decreased, demonstrating the positive impact of the policy across various sectors and regions. In terms of carbon emissions, Figure 4 presents the changes in carbon emissions across regions, further confirming the policy's effect on emission reduction. The data shows that carbon emissions declined in all regions, particularly in industrial and commercial areas.

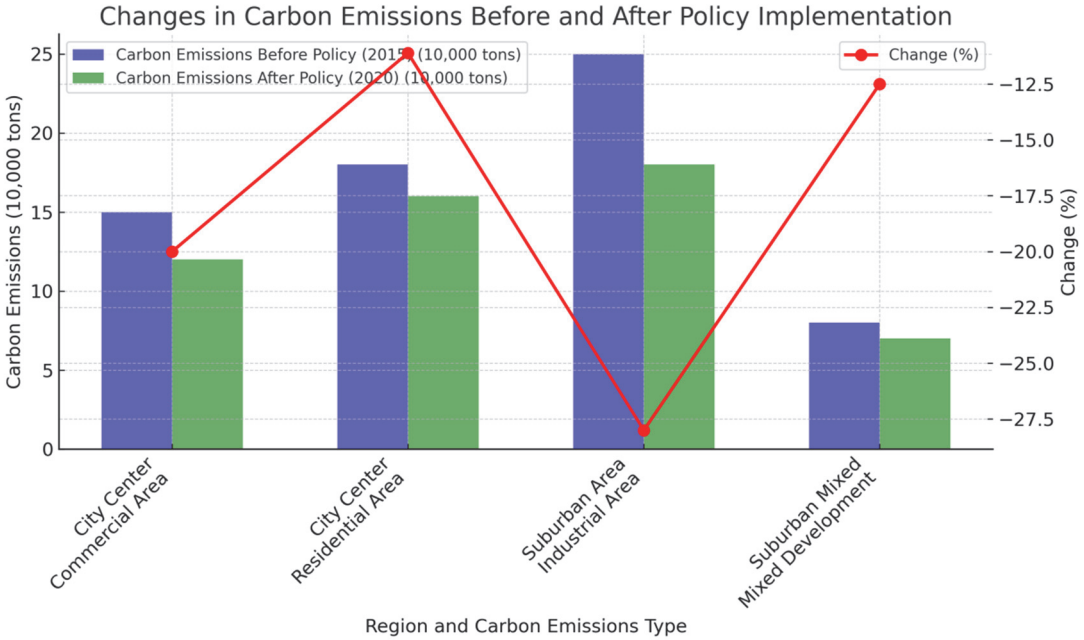


Figure 5. Changes in Carbon Emissions Before and After Policy Implementation

The data in Figure 5 shows that the low-carbon pilot policy effectively reduced carbon emissions, especially in the industrial and commercial areas, reflecting the success of the policy in promoting green transformation in industries and buildings. Finally, Figure 6 illustrates the impact of the low-carbon policy on the socio-economic development of different regions. By analyzing the relationship between GDP growth, carbon emissions, and energy consumption, it is evident that the low-carbon policy not only reduced carbon emissions but also supported economic growth.

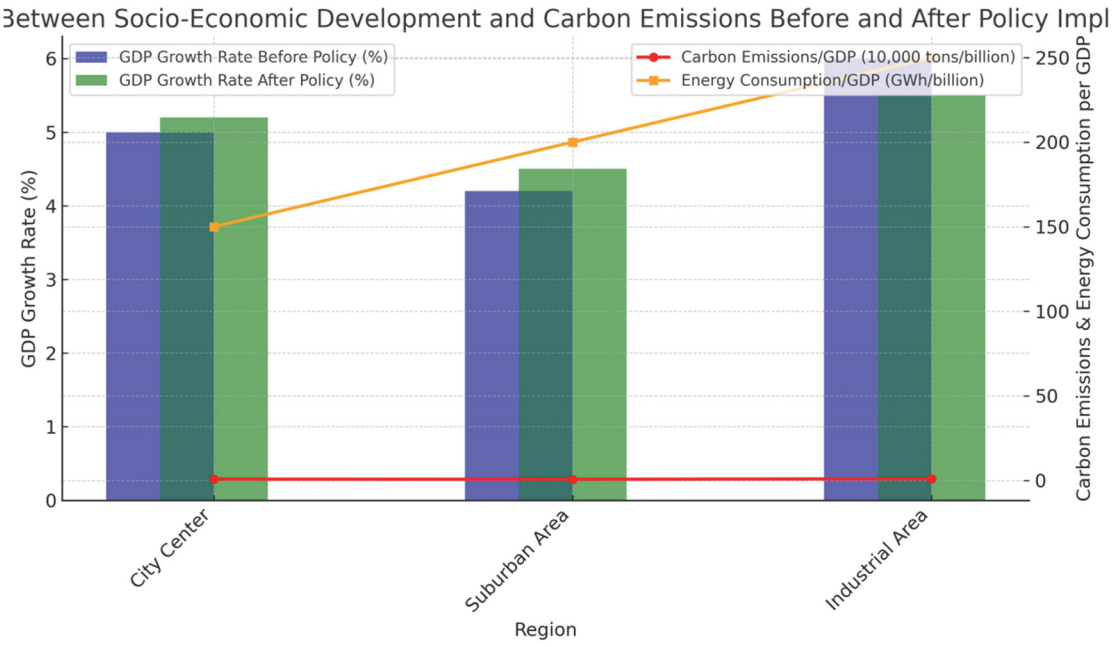


Figure 6. Relationship Between Socio-Economic Development and Carbon Emissions Before and After Policy Implementation

The Figure 6 indicates that after the policy implementation, the GDP growth rate in some regions slightly increased, while the ratio of carbon emissions and energy consumption to GDP decreased, showing that the low-carbon policy successfully reduced carbon emissions and energy consumption while promoting economic growth.In conclusion, the analysis of the tables above reveals that the low-carbon pilot policy has had a significant impact on land use, energy consumption, and carbon emissions in different regions, driving green transformation and low-carbon development in cities. Moreover, these data demonstrate that low-carbon policies effectively reduce carbon emissions while promoting sustainable economic development, providing crucial insights for future policy optimization.

## 5. Conclusion

This study analyzes the impact of low-carbon pilot policies on urban land use, energy consumption, and carbon emissions, and draws the following conclusions: First, the low-carbon pilot policies have achieved significant success in promoting the green transformation of cities. After the policy implementation, urban land use patterns changed, particularly in industrial and mixed development areas, with land use structures shifting towards green development. Second, the low-carbon policies have effectively reduced energy consumption, especially in high-energy industries and regions, significantly improving energy efficiency. At the same time, carbon emissions have generally decreased, demonstrating the policy's positive impact on reducing emissions.However, the implementation effects of low-carbon policies vary across regions. Although the policy has generally achieved good emission reduction results, some regions still face significant emission reduction pressures, necessitating further optimization of policy measures. Overall, low-carbon pilot policies have not only enhanced environmental benefits but also provided impetus for the green development of local economies.In the future, low-carbon policies should continue to strengthen regional differentiated management, further optimize the energy structure, and improve the application of green technologies to achieve a broader and deeper low-carbon transformation.

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