Research on the path of low-carbon city system construction mode based on energy consumption per unit output value method

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Abstract. In recent years, low-carbon research has become a research hotspot in urban system construction. Cities consume a large amount of carbon-based energy and are an important research object in low-carbon research. This paper first quantitatively analyzes the correlation between the three major industrial structures and the industrial energy consumption structure. At the same time, it studies the substitution of multiple energy sources, and obtains the mechanism of action of the low-carbon city system. Through the collection and analysis of data, the necessity of improving energy efficiency for the development of low-carbon cities has been proven. On the basis of this data analysis, this paper uses the method of energy consumption per unit output value to build a scenario analysis model of urban carbon emissions, puts forward four models of low-carbon urban system construction in terms of material flow, and gives the path planning and selection of low-carbon urban system construction.

1. Introduction

According to WWF research, 80% of global carbon emissions are concentrated in urban areas. At present, China is in the process of rapid urbanization and industrialization, and population concentration and economic growth have placed great pressure on the environment. Against the background of complex issues such as the greenhouse effect, increasing air pollution, and resource depletion, the development of low-carbon cities has been proposed. The low-carbon city system construction means that the city's energy consumption and CO₂ emissions are at a low level under the premise that the existing economic development speed and quality are unchanged or even better. Establish a resource-saving, environment-friendly, benign and sustainable energy ecosystem within the city [1]. Urban low-carbon transformation has become an important way to deal with climate change, protect the ecological environment, and improve the quality of urban life.

2. The function mechanism of low carbon city

At present, China is in a period of rapid urbanization, with an average annual increase in urbanization of about 1%. However, high energy consumption, low efficiency, high input, and low output have become fundamental problems in China's urbanization process, which has hindered the healthy and sustainable development of cities. For a long time, China's urbanization process has mainly considered insufficient attention to economic efficiency and resource efficiency. The theory and practice show that
low-carbon city construction is the fundamental way to improve urban efficiency and achieve sustainable urban development.

2.1. Major areas of urban carbon emissions

Urban carbon emissions include direct and indirect carbon emissions. It consists of five parts: Industrial carbon source \( M_I \): mainly carbon emissions from industrial processes and energy consumption; Building carbon source \( M_B \): the carbon emissions of public buildings other than residential buildings; Household carbon source \( M_F \): mainly the consumption of water, electricity and gas by urban residents is converted into direct or indirect carbon emissions; Transportation carbon source \( M_T \): mainly carbon emissions from urban social vehicles; Green carbon sink \( M_G \): carbon sink of vegetation such as urban greening; Total carbon emissions \( M \). Expressed in formula (1) as follows:

\[
M = M_I + M_T + M_F + M_B - M_G
\]

2.2. Develop low-carbon industries to promote the adjustment of urban industrial structure.

At present, in the construction of China's low-carbon cities, the energy use of various industries is irrational, the industry is generally single, and high energy consumption are serious [2]. Changes in the industrial structure will affect changes in the industrial energy consumption structure. In addition to the weak correlation between the proportion of the primary industry and its energy consumption ratio, the other two industries are relatively strong, and the tertiary industry is the strongest, with a correlation coefficient of 0.92, which is significantly correlated. As shown in Table 1. Therefore, it is necessary to develop low-carbon industries, adjust the industrial structure, promote "high processing" of the secondary industry, develop renewable resource industries and environmental protection industries, and vigorously increase the proportion of the tertiary industry.

| Proportion of energy consumption in primary industry | Proportion of energy consumption in secondary industry | Proportion of energy consumption in tertiary industry |
|---------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|
| Primary industry ratio 0.62 \( (0.058) \) | 0.742 \( ** (0.012) \) | 0.93 \( ** (0.00) \) |

Note: * indicates a significant correlation at the level of 10%, ** indicates a significant correlation at the level of 5%.

2.3. Improve energy efficiency to build a resource-efficient city

At present, China's overall energy efficiency is about 33%, which is about 10% lower than that of developed countries. The development of low-energy industries such as solar energy and wind energy in cities can effectively improve utilization efficiency through the development of advanced energy-saving technologies. Among the necessary energy in the city, the energy used for cooling, heating, domestic water, etc. can be supplied by any one of fuel oil, city gas, electricity, solar energy, and high-
temperature waste heat. Try to choose more than two forms of energy in one energy system [4]. Table 2 shows a comparison of several energy sources.

| Evaluation item | Solar energy | Natural gas | Traditional electricity | Wind power |
|-----------------|--------------|-------------|-------------------------|------------|
| Energy production | Conversion efficiency | × | △ | × | √ |
|                 | Carbon emission | × | △ | × | △ |
| Energy delivery | Conveying efficiency | × | Ⅴ | × | × |
|                 | Environmental protection | Ⅴ | △ | Ⅴ | Ⅴ |
|                 | Danger | Ⅴ | × | Ⅴ | Ⅴ |
| Energy supply   | Environmental protection | Ⅴ | △ | Ⅴ | Ⅴ |
|                 | Reliability | × | △ | Ⅴ | △ |
|                 | Danger | △ | △ | Ⅴ | Ⅴ |
| Energy use      | The cost | △ | Ⅴ | △ | Ⅴ |
|                 | Usage efficiency | △ | Ⅴ | △ | Ⅴ |
|                 | Safety | Ⅴ | △ | Ⅴ | Ⅴ |
|                 | Carbon emission | Ⅴ | △ | Ⅴ | Ⅴ |

Note: Ⅴ means good; △ means good, ▽ means normal, × means poor.

3. Low-carbon city system construction path

Considering the future carbon emission change trend of cities, combining various current policies and measures related to it, and the space and potential of low-carbon development of cities under different conditions, adopting strategies based on different situations. The energy consumption per unit output value method can be used to build a scenario analysis model of urban carbon emissions. \( M_0, GDP_0 \) means the total carbon emissions and GDP of the city in the base year, \( M_t, GDP_t \) express the total carbon emissions and GDP of the city in year t, \( \gamma \) and \( \theta \) are the annual decline rate of carbon emission intensity and the annual growth rate of GDP [5]. As shown in formulas (2) and (3).

\[
\frac{M_0}{GDP_0} \times (1 - \gamma)^t = \frac{M_t}{GDP_t} = \frac{M_t}{GDP_0 \times (1 + \theta)^t} \tag{2}
\]

\[
M_t = [(1 - \gamma) \times (1 + \theta)]^t M_0 \tag{3}
\]

3.1. Low carbon city system construction model

From the perspective of the material flow of the urban system, fuel flows into the urban system and is consumed through the production and consumption processes, while generating waste. Therefore, Low carbon city system construction model should include four aspects: low-carbon energy, low-carbon production, low-carbon consumption, and low-carbon emissions [6]. As shown in Figure 1.
3.2. Path Choice of Low Carbon City System Construction

3.2.1. Optimize urban spatial layout. Practice shows that if the city's spatial layout is unreasonable during the construction process, it will lead to an increase in carbon emissions. Therefore, low-carbon cities are mainly constructed by optimizing the internal structure of cities and rationally controlling the scale of land use. Among them, most of the foreign countries adopt ecologically-oriented compact development models to rationally control the scale of land use; and to optimize the internal structure of cities is to aggregate similar or related land use, or reasonably deal with idle land for greening to achieve space carbon reduction. Among them, optimizing the urban spatial layout is an important way to reduce energy consumption and reduce greenhouse gas emissions from the source.
3.2.2. Adjusting the city's industrial layout. In the process of urban planning, carry out industrial development planning that is compatible with the city's functional positioning, such as the migration of the primary industry to suburban areas that are closer to the city, the development of the tertiary industry in the central urban area, and the combination of urban and suburban areas mainly in light industry; around satellite cities Construct agricultural and high-tech zones; secondly, improve the planning access conditions for high-carbon industries according to the requirements of emission reduction targets.

3.2.3. Building a Low-Carbon Smart City. In the Internet era, smart cities are low-carbon cities characterized by big data and cloud computing. Therefore, using the Internet and the Internet of Things as a means of urban development and building a low-carbon smart city is an effective way to reduce urban carbon emissions. For example, through big data and cloud computing, provide effective convenience services for cities. Create a low-carbon smart community, actively use modern technology, realize information sharing, secondary use of resources, and realize intelligent and low-carbon management of the community [7].

4. Conclusion
In the process of rapid urbanization in China, a series of prominent urban problems such as resource exhaustion and environmental pollution have emerged. Low-carbon cities have brought new opportunities for China's urban development. Developing low-carbon industries to promote the adjustment of urban industrial structure, and improving energy efficiency to build resource-saving cities are important ways to solve this major problem and a key way to seize this new opportunity. The construction model of the low-carbon city system constructed by the energy consumption per unit output value method can better provide the path choice for the development of low-carbon cities.

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