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Development path of Chinese low-carbon cities based on index evaluation

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Abstract

This work takes the 36 cities from China's low-carbon pilot project as the research object and uses the carbon emission per capita and GDP per capita to categorize the 36 cities into four types to reveal their low-carbon development status; these four types are leading cities, developing cities, latecomer cities, and exploring cities. On the basis of an index system that quantitatively describes low-carbon development, this research analyzes the characteristics, development trends, and low-carbon development pathways of the four types of cities. According to the present situation and objectives of national emissions and considering the differences in development stages, challenges, and opportunities for each type of the city, this research presents recommendations for the low-carbon roadmap and the medium- and long-term (by 2030) emission trend routes of different types of regions in China.

Keywords: City; Low-carbon development; Index evaluation; Development path

1. Introduction

China accounts for about one-third of world's total greenhouse gas (GHG) emissions and is responsible for more than half of the world's increase in GHG emissions in the last 10 years (IEA, 2016). China presented its GHG control targets in its Intended Nationally Determined Contribution to achieve its peak CO_2 emissions around 2030 and is making its best efforts to peak early and to achieve other targets related to green, low-carbon development (CG, 2015).

City[1] is one of the key players in realizing GHG control targets. To promote the implementation of the target to control GHG emissions and explore the modes and paths of low-carbon development at the city level with different conditions and characteristics, China launched the low-carbon provinces and cities pilot project in July 2010 and approved three batches of a total of 87 low-carbon pilot areas, including 81 cities and 6 provinces. These pilots serve as representatives of different locations, resources, developing phases, challenges, and opportunities in low-carbon development. Therefore, a necessary task is to look into the current status of their carbon emission level, characteristics, developing trend, and challenges to illustrate low-carbon development strategies for distinct regions all over China.

The index system approach is a common methodology that is used to analyze and evaluate development at the city level both for policymaking and research. The core of establishing an indicator system is to determine the specific content and assessment standards. In China, some ministries and commissions have set up a series of index systems relevant to the concept of a low-carbon city, such as the National Ecological Garden City Standard (MOHURD, 2016), Evaluation Index System of New Energy Demonstration City (NEA, 2012), Construction Target System of National Ecological Civilization Demonstration Zone, Statistical Index System for Climate Change (NDRC, 2013), Green Development Index System (NDRC, 2016), and Evaluation Target System of Ecological Civilization Construction (NDRC, 2016).

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[1] In this study, the concept of carbon emission means direct CO_2 emission related to energy. CO_2 emission by external power is not included.

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Some influential research institutions in China have also explored evaluation index systems for low-carbon cities. The China Green Development Indicators formulated by Beijing Normal University established 57 indicators that are applied to 30 provinces and 100 cities (BNU, 2016). The three-level index system of "economic growth greening degree, potential bearing capacity of resource environment, and governmental policy support" as primary indicators highlights the urgency of China's green development. Tsinghua University, Columbia University, and McKinsey & Company regard basic needs, resource efficiency, environmental cleanliness, built environment, and commitment to sustainability as the framework and have formulated sustainable urban development indicators (CG, 2015). Eighteen of these indicators have been established and applied to 113 cities whose construction of environmental protection should be strengthened, as mentioned in the 11th Five-Year Plan of China. The Chinese Academy of Social Sciences took economic transformation, social transformation, low-carbon facilities, low-carbon resources, and low-carbon environment as the framework and formulated a comprehensive index system for China's low-carbon urban development evaluation (Zhu and Liang, 2012), and 10 indicators have been established and applied to 110 cities in China. The Chinese Academy of Sciences published a series of reports on China's sustainable development, including a sustainable development capability index system with municipalities directly under the central government, provinces, and autonomous regions as the main targets. A comprehensive evaluation was conducted through 45 elements and 233 indicators (Huang and Wang, 2014).

Internationally, several index systems related to the low-carbon city include the following: the international standard Sustainable City Development Index System defines and establishes methodologies for a set of indicators to steer and measure the performance of city services and quality of life (ISO, 2014); the Urban Indicators formulated by the United Nations Human Settlements Programme regard housing, social development, poverty eradication, and environmental management as the framework (UN-HABITAT, 2009); and the European green city indicators and Asian green city indicators formulated by the British Economist Intelligence Unit and Siemens (2011) take CO_2 emissions, energy, construction, transportation, water, waste and land use, air quality, and environmental governance as the main framework (Unit and Siemens, 2011).

From the above practices and researches, the index analysis is proved to be an effective approach to quantitatively describe, compare and rank a group of cities' development level with various parameters. The indicator amount of the above practices and researches are basically 20−100, with social and economic growth, policy system, and urban form usually taken into consideration. However up to now, there is still no official index system for the evaluation of Chinese city's low-carbon development and indicators for the determination of a low-carbon city are still under discussion, meanwhile the international experience for low-carbon city evaluation is not quite suitable for China's own characteristics. There are several other inadequacies from the existing practices and researches. First, the various local conditions in China are usually neglected and there is barely any classification analysis. Second, most of the existing index systems pay attention to historical value of the indicators and future trend of distinct cities is seldom analyzed. Third, due to public data resources limitation, there is always a gap of data to carry out analysis, especially when an index system has more than 20 indicators.

This study aims to propose low-carbon pathways for Chinese cities with distinct conditions, on a basis of index system approach. Considering representativeness in geography distribution, size and developing phase, we take the 36 cities in the first and second low-carbon pilot batches as the research object. The following sections are organized as following. Section 2 sets up an index system that could reflect the demand of low-carbon development for Chinese cities and categorize the pilot cities according to value of key indicators. Section 3 assesses the status, trend and challenges of low-carbon development for each type of cities by quantitative and qualitative analysis with index system analysis and case study approach. Section 4 summarizes the main findings.

2. Research methodology

2.1. Establishment of key indicators

On the basis of the research foundation of both the international and domestic indicator system experiences and a literature review of relevant theoretic research combined with the current unique situation of China, the indicator system should apply to the following principles:

- Scientific: It should comprehensively and objectively reflect low-carbon development and facilitate the gradual establishment of a low-carbon development model that can adapt to China's unique conditions.
- Universality: It should be simple and result-oriented rather than detailed to adapt to all regions.
- Operability: Data for the system should be available, and the information should be accessible.

By 2020, China is expected to have built a moderately prosperous society in all respects, as well as a prosperous, democratic, civilized, harmonious, and beautiful modern socialist country; and by 2035 China is committed to basically realize socialist modernization (Xi, 2017). The key driver for the carbon emission increase in China is GDP growth during the country's fast industrialization and urbanization process. On the basis of the above analysis together with integrated research purposes and data accessibility, we selected the following index to construct an evaluation and analyzed low-carbon pilot cities:

- **Carbon emission per capita**: Total energy-related CO_2 emissions of a region/permanent resident population of the region. This is the key indicator that represents a city's emission level.
- **Carbon emission per unit of GDP**: Energy-related CO_2 emissions per unit of GDP. This indicator reflects the

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