

## Empirical Research on Measurement Index System of Low-Carbon City

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**Keywords:** Low-carbon city; Measure index system; Carbon source ; Carbon sink

**Abstract:** Based on carbon source and carbon sink analysis frame in low-carbon economy theory, this paper constructs a low-carbon city measure index system which includes 13 indexes, which are production, transportation, construction and living carbon sources, forest and green land carbon sink.

### Introduction

Global climate change caused by carbon dioxide and other greenhouse gas emissions has become increasingly concerned by the international community. The United Nations adopted "United Nations Framework Convention on Climate Change" in 1992, aimed at slowing global warming. Intergovernmental Panel on Climate Change think that carbon emissions are mainly from urban areas (about 80% of the total carbon emissions)<sup>[1]</sup>. Therefore the development of low-carbon city for curbing climate change has important significance.

Current our country city's greenhouse gas emissions rank first in the world<sup>[2]</sup>, the problem of urban low-carbon need to be resolved. Under the background of global climate change, low-carbon city has become inevitable choice for sustainable development of city in the future. Through this study, on the one hand, we can provide a universal index system for evaluating low-carbon city. On the other hand, through the empirical analysis, we find out the characteristics and differences between different low-carbon cities, put forward countermeasures and suggestions to speed up the construction of low-carbon city, achieve the goal of "evaluation promotes construction".

At present, there are two ways to measure low-carbon city. One is using single indicator, such as urban per capita carbon emissions, proportion of clean energy accounted for primary energy, carbon emission intensity, etc.. S. T. Shwayri (2013) believed that per capita carbon emissions should be used instead of total carbon emissions to measure the level of low-carbon city, because human activities are root cause of greenhouse effect. Carbon emissions of some large cities in South Korea is undoubtedly huge, but by dividing the number of urban population, per capita carbon emissions tend to be very small, which complies with the standards of low-carbon green city<sup>[3]</sup>. Dai Yixin (2009), Tsinghua University, believed that the development level of low-carbon cities can be seen from intensity of carbon emissions<sup>[4]</sup>.

The other is using comprehensive index systems. S. Rory et al. (2013) from the target of ecological environment protection, according to the world bank data in 2010, using eight indicators of garbage harmless treatment rate, carbon productivity, carbon emissions per unit of building area, forest cutting, etc., assessed the level of ten low-carbon cities in United Nations and the results show that the level of Stockholm is the highest<sup>[5]</sup>. Lian Yuming (2012) considered low-carbon city is one kind of urban form in the era of ecological civilization. The construction of low-carbon city evaluation index system should base on the concept of ecological civilization, focuses on production and consumption, select indicators from human activities and ecological harmony symbiosis angle, eventually establish a set of comprehensive evaluation system, including 30 indicators, such as per capita water consumption, comprehensive utilization rate of industrial solid waste, air quality, etc.<sup>[6]</sup>.

Based on the analysis framework of carbon source-carbon source in low-carbon economy theory, this paper constructs a set of multidimensional measure index system of low-carbon city, using entropy value method carried on the empirical research to nine cities.

## Low-carbon City Measurement Index System Construction

Based on the carbon source and carbon sink analysis framework in low-carbon economy theory, the design method of index system is put forward, index selection principle is determined, a set of low carbon city measure index system is set up .

**Index System Design Idea.** In 2003, British government issued a white paper “Our Energy Future: Creating a Low-Carbon Economy”, in which the concept of carbon source and carbon sink is firstly introduced. H. W. Edwin et al. (2013), a famous economist, considered carbon source and carbon sink framework is core content of low-carbon economy theory<sup>[7]</sup>.

In low-carbon economy theory, the activities that release carbon dioxide into atmosphere are called "carbon source", the activities that remove carbon dioxide out from atmosphere are defined as "carbon sink". The significance of carbon source and carbon source analysis framework is, for the first time, "carbon" as a bridge between man and nature, establish a balance mechanism of carbon release and absorption. It explores carbon emissions and carbon uptake in a space range of human production and living in the city. Therefore, to measure the development level of low-carbon city, the dynamic mechanism of carbon source and carbon sink are carried out.

**Establishment of Index System.** According to design idea and selection principle of index system, this paper determined low-carbon city measure index system, as shown in Table 1. The index system is composed of 13 indexes. According to the above analysis, construction of low-carbon city is the process of reducing carbon sources and increasing carbon sink, we should consider positive and negative of the indicators. Carbon source indicators are negative for the development of low-carbon cities, so should be negative indicators, and carbon sink indicators should be positive indicators.

Table 1 Measurement Index System of Low-carbon Cities

target layer	Standard layer	factor layer	index layer	Unit	Positive and negative
Low carbon city index	carbon source	Production carbon source	Energy intensity( $X_1$ )	Tons of standard coal / million	—
			Carbon emission intensity( $X_2$ )	Tons / million	—
			Carbon emissions per unit of industrial GDP( $X_3$ )	Tons / million	—
			Sulfur dioxide emissions per unit of industrial GDP( $X_4$ )	Tons / million	—
		Transportation carbon source	Private cars per one hundred people( $X_5$ )	Vehicle / one hundred	—
			proportion of non-clean energy vehicles( $X_6$ )	%	—
			transportation carbon emissions per capita( $X_7$ )	Tons/ person	—
		construction and residents living carbon source	proportion of non-green building( $X_8$ )	%	—
			Residents per capita electricity consumption( $X_9$ )	KWh / person	—
	Carbon sink	Forest Carbon sink	Planting area per hundred people( $X_{10}$ )	Square meters / person	+
			Forest coverage( $X_{11}$ )	%	+
		Greenland Carbon sink	Proportion of green area accounted for the total area of the city( $X_{12}$ )	%	+
			Per capita green area( $X_{13}$ )	Square meters / person	+

## An Empirical Analysis of Low-carbon City Measurement of 9 Prefecture-level Cities in Guizhou Province

**Data Collection and Standardization.** The original data come from “China Statistical Yearbook”, “China Urban Statistical Yearbook”, “China Environmental Statistics Yearbook”, “Guizhou Statistical Yearbook”, “Guiyang Statistical Yearbook” and local statistical yearbook of other provinces and cities in 2014 year.

Because the dimensions of 13 indicators original data are different, in order to avoid big calculation results error, it should be standardized raw data. Considering the comparison of 9 low-carbon cities, the method of extreme value method is used to carry out the standardization. First, determine the maximum and minimum values of each index sequence. Each index original value minus the minimum value of the sequence, then divided by the difference between maximum and minimum value. The 468 original data standard values of 13 columns 36 lines are obtained.( due to space is limited, data is slightly).

**Index Weight Calculation Formula.** The entropy method can objectively determine the weights according to the index value, especially suitable for index system of multi index synthesis. Therefore, we calculate the index weight by entropy method.

Set  $U_{ij}$  as the index value of line  $i$  column  $j$ ,  $m$  is the number of rows,  $K$  is the number of columns,  $f_j$  and  $p_j$  respectively is weight value and entropy of standardized data in column  $J$ .  $A$  expresses index value is positive or negative sign. Then

$$f_j = \frac{1 - p_j}{\sum_{j=1}^k (1 - p_j)} \quad (1)$$

$$p_j = A \cdot k \sum_{i=1}^m \left[ \left( \frac{u_{ij}}{\sum_{i=1}^m u_{ij}} \right) \cdot \ln \left( \frac{u_{ij}}{\sum_{i=1}^m u_{ij}} \right) \right] \quad (2)$$

Equality (1) and equality (2) are calculation formulas of index weight.

**Measurement Results and Analysis.** Standardization value is substituted in weighted average formula (Equation 3). When  $g=1$  and  $h=13$ , low-carbon city index of 9 pilot cities can be obtained, as shown in table 2.

$$\text{Assessment results} = \sum_{j=g}^h (f_{ij} \cdot u_{ij})_{i=1,2,\dots,9} \quad (3)$$

When  $g=1$  and  $h=4$ ,  $g=5$  and  $h=7$ ,  $g=8$  and  $h=9$ ,  $g=10$  and  $h=11$ ,  $g=12$  and  $h=13$ , we can obtain production carbon source, transportation carbon source, construction and residents living carbon source, forest carbon sink, Greenland carbon sink of 9 cities, as shown in table 2.

Table 2 Measurement Results of 9 Cities in Guizhou Province

City name	Low-carbon city index	Production carbon source	Transportation carbon source	Construction and residents living carbon source	Forest Carbon sink	Greenland Carbon sink
Anshun	0.829	0.333	0.175	0.223	0.872	0.924
Zunyi	0.81	0.087	0.383	0.127	0.759	0.89
Guiyang	0.802	0.252	0.052	0.111	0.978	0.943
Qiandongnan	0.797	0.359	0.031	0.118	0.804	0.982
Qianxinan	0.785	0.041	0.499	0.303	0.703	0.718
Qiannan	0.778	0.042	0.425	0.296	0.421	0.898
Bijie	0.773	0.068	0.411	0.358	0.823	0.755
Tongren	0.758	0.079	0.479	0.287	0.81	0.731
Liupanshui	0.258	0.802	0.295	0.762	0.693	0.426

From low-carbon city index, low-carbon city level of Anshun is the highest, its index value is 0.829. Low-carbon city level of Liupanshui is the lowest, its index value is 0.258. For carbon sources, production carbon source, transportation carbon source, construction and residents living carbon source of Anshun respectively is 0.333,0.175,0.223, and that of Liupanshui is 0.802,0.295,0.762. In contrast, the negative impact of three carbon sources on Anshun is small. For carbon sink, forest carbon sink, Greenland carbon sink of Anshun respectively is 0.872、 0.924, and that of Liupanshui respectively is 0.693、 0.426. It shows that the positive effects of forest carbon sink, Greenland carbon sink in Anshun are strong, vigorously promote low-carbon city construction.

## **Policy Suggestions**

Clustering analysis was carried out on low-carbon city, which is helpful for government decision-making departments making targeted policies and measures for each category of cities to better promote the process of urban low-carbon.

First of all, for Anshun, Zunyi, etc, effectiveness is outstanding in reducing production carbon source. Because production low-carbon level is already quite high, in the future, we can focus on mining potential of saving energy and reducing emission from transportation carbon source, construction and residents living carbon source.

Secondly, low carbonization of Guiyang and Qiandongnan should focus on the transportation sector. By developing subway, light rail, intercity express train and other public transport network promote new energy vehicles, and using other measures reduce transportation carbon emissions.

Then, For Southwest Guizhou and South Guizhou, which construction and residents living carbon source is more prominent, there are two ways to promote their low-carbon development. On the one hand, promote green building standards and energy saving building materials; on the other hand, strengthen propaganda low-carbon life concept, encourage residents consciously practice low-carbon lifestyle.

For Bijie, Tongren and other carbon sinks rich cities, we should try our best to protect forest and green resources. At the same time, take appropriate measures to reduce all kinds of carbon sources, try to keep the good situation that carbon sink is greater than carbon source.

At last, for Liupanshui with low-ranking, strategic planning of low-carbon city development should be made. Low-carbon planning of three major carbon sources: production, transportation, construction and residents living are incorporated into the overall urban planning, develop low-carbon industry structure system, improve energy utilization efficiency, push green transportation, promote urban construction to low carbon transition, lead residents to low carbon consumption, strongly advocated afforestation and roof greening, speed up urban low-carbon development.

## **Acknowledgements**

Research on evaluation of tobacco farmers classification and differential management in southwestern Guizhou (2011-15); Study on the mechanism of foreign assets of tobacco farmers cooperatives inclusive (2015-9); Guizhou Province Science and Technology Fund project ( Qiankehe J [2015] No. 2028); Science and technology project of China National Tobacco Corp Guizhou Branch (201224); National social science fund project (14CJL032)

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