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The study on how to evaluate and improve the low-carbon economic development level of resource-based cities

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ABSTRACT

The resource-based city cannot develop without resources, however, with the development of the entire economy and society of our country, it also needs to be transformed and upgraded. Propelling low-carbon economy can ensure a sustainable development and improve its development quality. At the same time the evaluation of low-carbon economic development level is helpful for city planning. In this paper, it constructs an indicator system to evaluate low-carbon economic development level. The system involves 5 second grade indicators, in each of which includes many third factors. Then the system is applied to evaluate the low-carbon economic development level of T city. Specifically through calculating the low-carbon economic development index (F), it evaluates the low-carbon economic comprehensive level and the development level of second grade indicators in a quantitative way and meanwhile analyzes them qualitatively and finally it provides 4 pieces of advice to improve economic level. By combining these two approaches and taking quantitative approach as the main study approach, it studies the low-carbon economic development level of T city that represents the resource-based cities and these approaches are reliable and can be taken as a reference for further study and other researchers.

KEYWORDS

Resource-based city; Low-carbon economy; Evaluation of development level; Quantitative study.

INTRODUCTION

Resource-based cities refer to the cities that mainly based on the exploitation and processing of mineral, forest and other natural resources. The developing process of resource-based city can be classified into two modes: one is "city after mineral", namely the city appears and develops due to the exploitation of resource; another is "city before mineral", that is, the city has existed before discovering the mineral, which in turn accelerates the city's development. Compared with other cities, these cities have more strong dependence on the mineral they have discovered, which sometimes will also lead to the decline of cities. To realize the sustainable development, these cities may choose many new roads to go, of which the road of developing low-carbon economy is more common and effective. Western developed countries, such as Britain and America, have much experience on this road. However, with the developing of economy and society, such developing countries as China and Brazil are emerging in the exploration of developing low-carbon economy. In this paper, it will study the low-carbon economic development of resource-based cities in China and it will focus on study how to evaluate the development level of such cities and put forward relative solutions to improve their development. Thus this paper chooses T city as a study example and by constructing the evaluation system it evaluates the development level and provide relative solutions. The study approach is feasible and in reality the study perspective and conclusion are practical.

THE CONSTRUCTION OF INDICATOR SYSTEM ON EVALUATING LOW-CARBON ECONOMIC DEVELOPMENT LEVEL

The Construction of Hierarchical Structure Model

To construct the indicator system of T city, after combining the city's concrete condition and other relative research, the study applies the approach of expert consultation to construct the structure model (See Figure 1). In the following hierarchical model, we can get that second grade indicators involve low-carbon output, low-carbon consumption and other three indicators and each second grade indicator includes several third grade indicators.

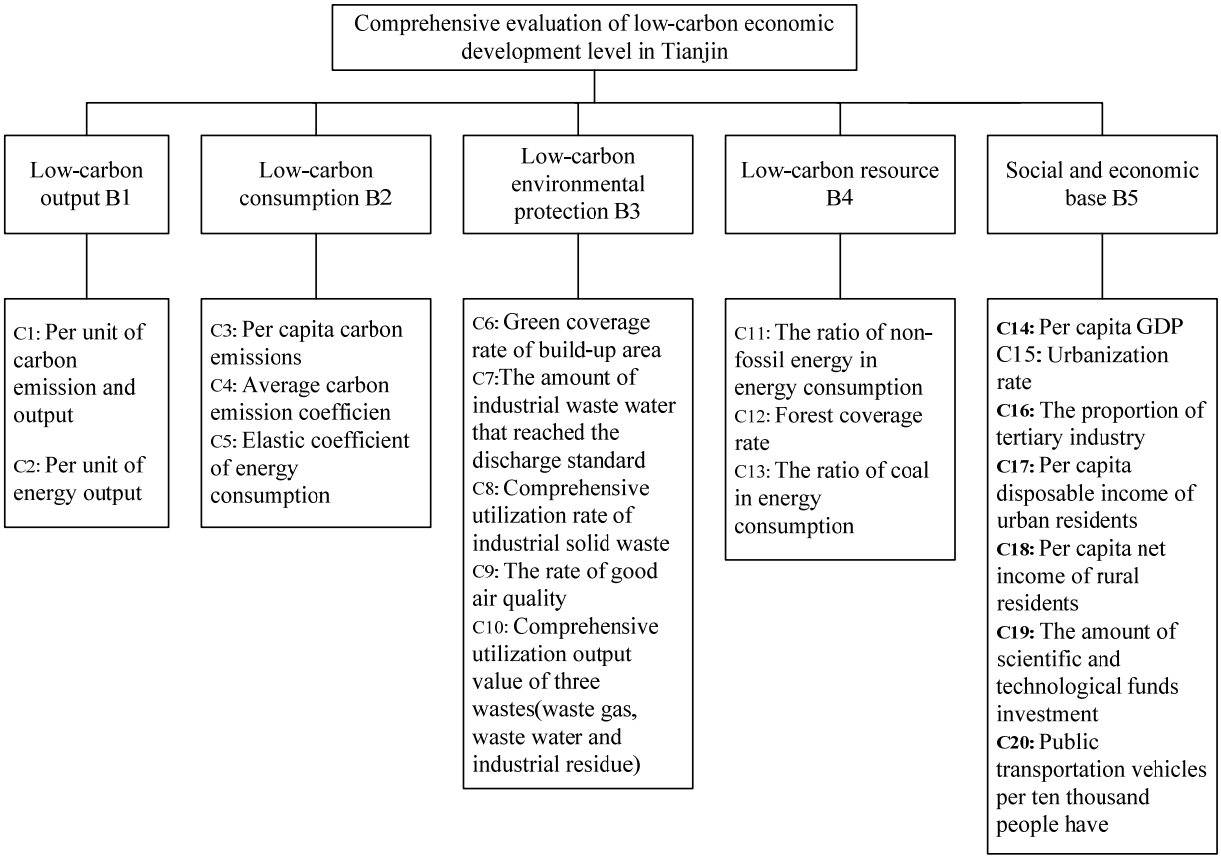

Figure 1: Hierarchical Structure Model about the Comprehensive Evaluation of Low-carbon Economic Development Level in Tianjin

The Construction of Judgment Matrix

To construct the judgment matrix, firstly we should rely on the judgment standards to judge the relative importance of each indicator by marks. From the following TABLE 1, we know that the the study applies the common and privileged "

1-9 scale method ” to mark the relative importance of indicators. And after judging the importance, the judgment matrix can be constructed as described in TABLE 2.

TABLE 1 : 1-9 Scale Method

Scale	Meaning
1	Two factors are equally important.
3	Compared with the latter, the former is relatively important.
5	Compared with the latter, the former is obvious important.
7	Compared with the latter, the former is more important.
9	Compared with the latter, the former is extreme important.
2、4、6、8	Judging the intermediate value of adjacent factors

TABLE 2 : Judgment Matrix

	Social and economic base (a1)	**Low-carbon resource (a2)**	**Low-carbon environmental protection (a3)**	**Low-carbon consumption (a4)**	**Low-carbon output (a5)**
Social and economic base (a1)	1	1/2	2	3	1/3
Low-carbon resource (a2)	2	1	2	1	1/2
Low-carbon environmental protection (a3)	1/2	1/2	1	1/2	1/3
Low-carbon consumption (a4)	1/3	1	2	1	1/2
Low-carbon output (a5)	3	2	3	2	1

The judgment matrix described in TABLE 2 can be used the form of matrix to express as:

$$A=(a_{ij})=\begin{bmatrix} 1 & 1/2 & 2 & 3 & 1/3 \\ 2 & 1 & 2 & 1 & 1/2 \\ 1/2 & 1/2 & 1 & 1/2 & 1/3 \\ 1/3 & 1 & 2 & 1 & 1/2 \\ 3 & 2 & 3 & 2 & 1 \end{bmatrix} \quad \textbf{(1)}$$

Indicator Weight

Indicator weight refers to the contribution rate of this indicator to first grade indicator. There are many methods, of which the root method is chosen to calculate the indicator weight. Applying this method to normalize vectors from formula 1 and the final vector we obtained is the weight vector of the indicator we needed.

According to root method, firstly using the following formula to calculate the product M_i of every elements in each row of Formula 1:

$$M_i=\prod_{j=1}^{5} a_{ij}$$

Secondly, using the following formula to calculate the 5 times root W_i of M_i:

$$W_i=\sqrt[5]{M_i}$$

Then, to normalize W_i according to the following formula:

$$W_i = \frac{W_i}{\sum_{i=1}^{5} W_i}$$

Finally, to get the following matrix:

A	a_1	a_2	a_3	a_4	a_5	M_i	W_i	$\tilde{W}_i$
a_1	1.000	0.500	0.333	0.5000	2.000	35.000	2.048	0.2551
a_2	2.000	1.000	0.5000	1.000	2.000	0.167	0.699	0.1552
a_3	3.000	2.000	1.000	1.000	3.000	0.055	0.561	0.1000
a_4	2.000	1.000	1.000	1.000	3.000	0.500	0.871	0.1246
a_5	0.500	0.5000	0.333	0.333	1.000	6.000	1.431	0.3651

(2)

From Formula 2, the weight vector of second grade indicators can be originally determined as $(0.2551 \;\; 0.1552 \;\; 0.1000 \;\; 0.1246 \;\; 0.3651)$.

Consistency Check

It is an important method that can ensure the analysis results of model can match with the actual condition and can be processed as follows,

(1) Firstly to calculate the maximum eigenvalue $\lambda_{\max}$ of judgment matrix A as follows,

$$D = (d_i)_{5\times 1} = A \times \tilde{W}_i^T = (1.8595 \; 0.6289 \; 0.5087 \; 0.7899 \; 1.297)^T$$

Therefore, to calculate the maximum eigenvalue $\lambda_{\max}$ on basis of the following formula,

$$\lambda \max = \sum_{i=1}^{5} \frac{d_i}{5 \times w_i} = 5.0806$$

(2) Then according to the following formula, to calculate the consistency indicator (CI).

$$CI = (\lambda_{\max} - n) / (n-1) = 0.02015$$

(3) Based on the calculation above and the following formula, to calculate the random consistency rate (CR).

$$CR = \frac{CI}{RI} = \frac{0.02015}{1.12} = 0.0179$$

The values of random indicator (RI) are described in TABLE 3.

TABLE 3 : Random Indicator

Order n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

If $CR < 0.1$, the judgment matrix will pass the consistency check, or it will need to be corrected. According to this judgment standard, in this study CR has been calculated as $0..179 < 0.1$, which shows that the judgment matrix has passed the check. And the weight vector of second grade indicator we calculated above can also be used to evaluate the development level.

$$\tilde{W}i = (\tilde{w}_1, \tilde{w}_2, \tilde{w}_3, \tilde{w}_4, \tilde{w}_5) = (0.2551 \; 0.1552 \; 0.1000 \; 0.1246 \; 0.3651)$$

The method of calculating second grade weight also can be used to calculate third grade weight. Because of limited space, the calculation steps are omitted here. As is shown in TABLE 4, after calculating and aggregating, finally in this paper it obtains the indicator system and weight of low-carbon economic development level in T city.

TABLE 4 : The Indicator System and Weight of Low-carbon Economic Development Level in T city

First grade indicator	Second grade indicator	Weight	Third grade indicator	Weight	Indicator attribute
Low-carbon economic development level in T city	Low-carbon output	2.551	Per unit of energy output	0.1275	Positive
			Per unit of carbon emission and output	0.1275	Positive
	Low-carbon consumption	0.1552	Elastic coefficient of energy consumption	0.040 4	Inverse
			Average carbon emission coefficient	0.050 8	Inverse
			Per capita carbon emissions	0.064 0	Inverse
	Low-carbon environmental protection	0.100	Comprehensive utilization output value of three wastes (waste gas, waste water and industrial residue)	0.009 5	Positive
			The rate of good air quality	0.012 5	Positive
			Comprehensive utilization rate of industrial solid waste	0.020 6	Positive
			The amount of industrial waste water that reached the discharge standard	0.020 6	Positive
			Green coverage rate of build-up area	0.036 7	Positive
			Forest coverage rate	0.062 3	Positive
	Low-carbon resource	0.1246	The ratio of coal in energy consumption	0.031 2	Inverse
			The ratio of non-fossil energy in energy consumption	0.031 2	Positive
			Public transportation vehicles per ten thousand people have	0.019 1	Positive
			The amount of scientific and technological funds investment	0.034 6	Positive
		0.3651	Per capita net income of rural residents	0.082 3	Positive
			Per capita disposable income of urban residents	0.106 3	Positive
			The proportion of tertiary industry	0.032 6	Positive
			Urbanization rate	0.032 6	Positive
			Per capita GDP	0.057 7	Positive

THE EVALUATION OF LOW-CARBON DEVELOPMENT LEVEL IN T CITY

In the second part of this paper, the indicator system and its weight to evaluate low-carbon development level has been constructed. Then the development level should be evaluated by means of the combination of quantitative approach and qualitative approach.

The data we used come from *China Energy Statistical Yearbook*, *Tianjin Statistical Yearbook* and *Tianjin National Economyand Society Developed Statistical Bulletin* directly or indirectly. Because the dimensions of these data are different, they can be used only after being normalized that has been described in the second part of this paper.

Evaluation Indicator

The comprehensive weighted method can effectively balance the difference between different indicators to make the indicator have a strong comprehensive. So this study decides to apply this method to study the low-carbon economic development level of T city and the evaluation indicator can be calculated by the following formula.

$$F_i = \sum_{j=1}^{n} w_{ij} \bullet x_{ij} \quad \textbf{(3)}$$

$$F = \sum_{i=1}^{5} F_i = \sum_{i=1}^{5} \sum_{j=1}^{n} w_{ij} \bullet x_{ij} \quad \textbf{(4)}$$

In Formula 3 and 4, F refers to the indicator of low-carbon economic development, the final parameter we need to calculate, x_{ij} is normalized data, n the number of each grade, w_{ij} the weight, F_i the index (evaluation value) of second grade indicator. The index of 5 second grade indicator and first grade indicator is calculated by the Formula 3 and 4.

Analysis about Evaluation Result

The scholars in and abroad have done more in studying the evaluation of low-carbon economic development level and by referring to these study conclusions, this study have set evaluation index F as below.

(1) When $F \in [0,60]$, the region stays in the high carbon economic level;

(2) When $F \in [60,80]$, the region stays in the medium carbon economic level;

(3) When $F \in [80,100]$, the region stays in the low carbon economic level.

From Figure 2, F value has risen from 28.13 in 2005 to 79.27 in 2010, especially after 2007, it rises rapidly. According to the standard described above, before 2010 though T city has very close to but still not reached the low-carbon economic level. But in 2009, it goes into medium carbon economic level, which shows it has close relationship with the whole economic situation.

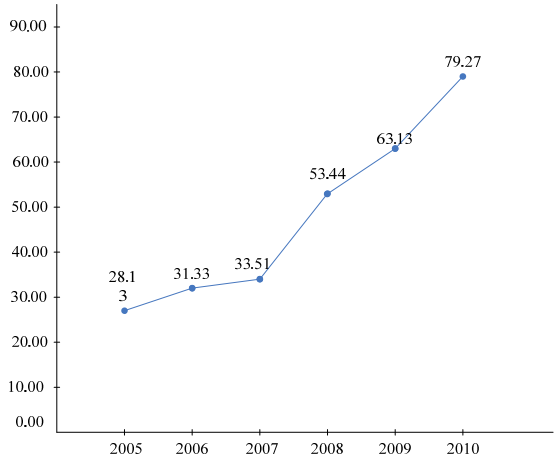

Figure 2 : Comprehensive Index of Low-carbon Economic Development Level in T City

As shown in Diagram 3, it has a great difference in the annual change of subsystems in T city. Social and economic base subsystem rises rapidly and performs the best, the reason of which is that the development of tertiary industry and the improvement of science and people's living standard result in people have more recognition for low-carbon economy. After the year of 2008, low-carbon output subsystem speeds up suddenly resulting from the increase of energy consumed in the development process of this city. Low-carbon consumption subsystem has stayed in a tendency of decrease owing to the decrease of severe pollution from the optimization of energy structure. Low-carbon environmental protection subsystem does not change obviously because of the contribution of comprehensive utilization of waste and the decrease of green coverage resulting from the construction of projects. Low-carbon resource subsystem has risen gently, which reflects the energy consumption depends on the coal on a large scale and on the other hand it widely promotes the clean energy.

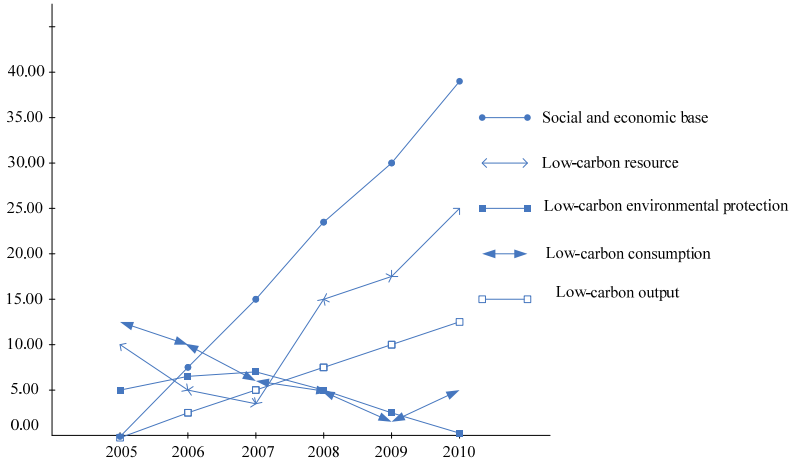

Figure 3 : Subsystem Index of Low-carbon Economic Development Level in T City

COUNTERMEASURES AND SUGGESTIONS TO IMPROVE THE LOW-CARBON ECONOMIC DEVELOPMENT LEVEL OF T CITY

Optimizing Energy Structure and Promoting Low-carbon Resource

Though the proportion of coal consumption occupied in energy structure is gradually decreasing in T city, until the end of 2010 the proportion of coal is still large, about 65%, higher than the sum of other types of energy, which reflects that the energy structure in T city can be optimized on a large scale. In particular, we should provide the support of policy, tax and energy subsidize to encourage mineral enterprises and residents to use natural gas and gas, liquid and hydrogen conversed and made from coal and other clean energies. At the same time, encourage capitals to enter into such energy's production areas as solar, wind and nuclear energy, making the technology and cost of these areas obtain competitive advantage.

Optimizing Industrial Structure and Promoting the Low-carbon Industry

From the economic perspective, we know the industrial structure determines the energy structure, that is, the constitution and scale of the first, second and third industry will decide the consumption amount of various energy and its proportion. The third industry consumes energy the least and the most energy it consumed is clean energy. The proportion of the third industry occupied in national economy of Europe, the United States and other developed countries reaches above 70% and the equal proportion of China is much lower. The economic statistical data of T city in 2010 shows that the third industry occupies in GDP about 47%, lower than the developed countries even the developed non-resource cities in east of China. Therefore, it needs to develop the third industry for T city and gradually eliminates the high energy consumption projects in the second industry to optimize its industrial structure.

Conducting to Optimize Consumption and Promoting to Realize Low-carbon Consumption

Social consumption basically determines social production. Therefore, to realize low-carbon economic development the society must be conducted to adjust the consumptive habits and awareness to let the public recognize the development of low-carbon economy has close relationship with their health, life quality and consumptive cost. According to the analysis described in Part 3, the low-carbon consumptive index has a tendency to decline annually, which shows that the low-carbon consumption has obtained public's support and achieved obvious achievements. However, it also needs to be supported by promoting, policies and taxes and encouraging the public to participate in positively in the following aspects as low-carbon transportation and the preservation and recycling of resources.

Strengthening the Construction of System to Provide Institutional Support for Low-carbon Economic Development

Developing low-carbon economy needs the authorities to conduct, encourage, support and regulate. Thus T city should continue to explore in system construction and from the analysis of Part 3, we know its low-carbon economy has owned good social and economic base that creating a good social condition for system's establishment and implementation. It should improve relative laws, tax policies and energetic industrial examination and make the development plan and performance appraisal of clean energy to provide unified, regulated and effective institutional support. Meanwhile, by referring to the experience to develop low-carbon economy in developed cities or countries, it could pay attention to the market mechanisms of carbon trading.

CONCLUSION

Developing low-carbon economy is a reliable path to transform and upgrade for resource-based cities. As a typical resource-based city, its early development heavily depends on high-consumption and high-pollution energies, like coal. However, with the expansion of city, the transformation of the entire economy, the optimizing of industrial structure and the higher requirements of city environment citizen put forward, it must optimize the energy structure, adjust industrial structure and conduct the public to improve the energy consumption and propel low-carbon economic development in the system aspect.

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