Evaluation Method of Provincial Low-carbon Energy Power Development

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Abstract. How to effectively evaluate the low-carbon energy development in the provincial level is with great of significance. In this paper, a provincial index system for the assessment of low-carbon energy development is constructed, which consists of three layers, i.e., the basic energy data, the analytical index and the evaluative index layers. Through the construction of the development scenario, the basic energy data are selected, the analytical indicators are measured and the development of low-carbon energy at the provincial level is evaluated from the perspectives of safety, economy, cleanness, efficiency and coordination. Our proposed method is applied to the assessment of low-carbon energy development in a central province, where the weight of the specific evaluation index can be determined by the analytic hierarchy process and expert opinion method. Besides, the data of a central province can be used to form a case application analysis result. The findings may provide some useful insights for underpin government decision-making.

Introduction

China has a commitment to carbon dioxide emissions to peak around 2030, and will try to reach peak at an earlier date. It is necessary to build ecological civilization and realize low-carbon development. At present, China's economy is shifting from high growth stage to high quality development, and the provinces are actively exploring the road of transformation and development that is in line with the provincial situation, in which the transformation of energy and electricity is of vital importance. On the one hand, the development of energy and electricity should take into account the demand and capacity of local economic and social development for energy and electricity, while also considering the national carbon emission requirements. With the in-depth study of low-carbon energy and the extensive implementation of various measures, the assessment of the development of low-carbon energy power has been mentioned as an important position. The assessment of provincial low-carbon energy development is an important part of the assessment of low carbon energy development in the whole society. The assessment of the development of low-carbon energy at the provincial level provides scientific and effective support for provincial management decision makers, which can serve as an effective basis for policy-making and public communication of government departments. A comprehensive evaluation model for low-carbon energy in Beijing was proposed in [1]. [2] put forward a comprehensive evaluation method for China's low-carbon economic development. However, there are few studies on the evaluation methods of low-carbon energy and electric power development at the provincial level at present, and it is urgent to conduct research on the evaluation methods of low carbon energy in the provincial level. More literature study energy production and consumption from the perspective of economic development. For example, [3] studied the threshold of the growth rate of energy consumption among different regions with the help of the economic growth model. [4] mainly studied the relationship between clean energy consumption and economic growth. [5] analyzed the current situation of energy development in China under the
low carbon economy and puts forward corresponding strategies. From the point of view of building evaluation system, [6] uses the method of analytic hierarchy process and expert survey to determine the weight of specific evaluation index, and has achieved a better application effect. However, the method is aimed at a single energy saving project, and no macroscopic evaluation system and method for power development of low carbon energy at provincial level are studied. Therefore, it is necessary to establish an effective evaluation index system of low carbon energy and an objective and accurate assessment method.

**Provincial Low-carbon Energy Development Assessment Method**

The development of low-carbon energy is related to economy, environment, technology, safety and so on. The development of energy power is closely related to the sustainable development of other aspects, so its evaluation index and the establishment of evaluation methods involve more contents.

**Determination of the Evaluation Indicator**

The establishment of index system is a key step in the evaluation of energy low-carbon development. The number of indicators in the indicator system must be able to comprehensively reflect the development status of low-carbon energy. The more indicators are not better, although the more indicators can reflect the characteristics of energy power in a more comprehensive way, which inevitably brings difficulties to the collection of evaluation indicators, and also increases the cost of system evaluation. Correspondingly, the number of indicators is small, which can reduce the cost of evaluation and simplify the evaluation process, but it is difficult to fully reflect the situation of sustainable development of energy power. Therefore, we should take the right amount of the core indicators to establish low-carbon energy electric power development evaluation index system, so that the establishment of low-carbon energy development evaluation index system can fully reflect the development of low carbon energy, and effectively reduce the cost of assessment. It is necessary to use certain methods to select the evaluation indexes to establish a relatively complete evaluation index system.

Index system construction principle: The first is the combination of universality and particularity. We need to consider the universality of the evaluation index system, comparability and external recognition and consider different regional energy industry attribute characteristics at the same time. The second is the combination of comprehensiveness and representativeness. The framework of evaluation index system can fully reflect the development of energy and electricity. Try to reflect important aspects with the least indicator and give full consideration to the availability of data. The third is the combination of quantitative index and qualitative index. Try to select quantitative (hard) indexes, and pay attention to the selection of qualitative indicators. As far as possible choose relative index, a small amount of using absolute index.

![Indicator system building flow chart.](image-url)
Index selection process: Based on the current research on the evaluation index system and energy development index system of low-carbon energy development at home and abroad, the present situation of energy development assessment method is summarized and the index system is established. Generally speaking, the process of index selection is shown in the figure 1.

To establish an evaluation index system based on the above principles is like this. The low carbon energy development assessment system in the province is generally made up of three levels (energy base data, analytical index, and evaluative indicators). Through the construction of the development scenario, the energy basic data is determined, the analytical indicators are measured, and the quality of energy development at the provincial level is comprehensively evaluated from the perspective of coordinated and sustainable development. Among them, the analytical indicators are based on the statistics, analysis and extraction of provincial energy basic data. Provincial energy basic data is used to describe the development characteristics of low-carbon energy at the provincial level, which are divided into six categories: energy efficiency, energy structure, energy supply and demand, energy transfer, energy security and energy environment. The evaluation index is constructed from five aspects of safety, economy, cleaning, efficiency and coordination. The evaluation of the development of low carbon energy at the provincial level becomes clear through the establishment of the overall index of sustainable development level. The structure of the evaluation system is shown in figure 2.

![Figure 2. The schematic of provincial low-carbon energy development evaluation index system.](image)

**Evaluation Criteria and Methods**

1) Set up a weighted set

Determining the index weight is the key link of comprehensive evaluation and the accuracy of the relationship evaluation result. In view of the difficulty in quantitative evaluation of some indexes in the index system, the analytic hierarchy process (AHP) and expert opinion method are used to calculate the weights of indicators and obtain the two comparative judgment matrices of experts on the importance of indicators. To calculate the weights of each index by applying AHP method, and to optimize and adjust the weights of indicators by expert opinions in the system to determine the final weight.

2) Evaluation standard

Security: It must meet the energy supply and demand balance in the province. The energy supply is sufficient and reliable, and the demand can be satisfied continuously, without the "lack of energy".

Economy: Its prices have advantages compared to all kinds of energy (coal, oil, gas, electricity, etc.). Energy cost is accepted by energy consumers.
Clean: It has achieved significant growth in emission reduction, reducing greenhouse gas emissions, reducing acid rain, and a significant increasing in the proportion of clean energy in primary energy, and the proportion of electricity in the terminal energy.

Efficient: Energy consumption per unit of GDP, energy efficiency and energy intensity.

Coordination: According to the trend of economic, pollution emission and energy consumption, we can estimate the position of the province in the whole country, and compare it with the neighboring provinces.

3) Index normalization

Considering that there are many qualitative indexes in the evaluation, this study will adopt a fuzzy evaluation method. In the process of normalization of indicators, all indexes will be normalized to an optimal value, and each indicator will be between 1 and 10. The evaluated object has excellent performance in this index, when the value is 8~10; The evaluated objects have good performance in this index, when the value is 6~8. The evaluated object has the general performance in this index, when the value is 4~6; The evaluated object has a poor performance in this index, when the value is 2~4; The evaluated object has poor performance in this index, when the value is 0~2.

Case Analysis

By collecting energy and electricity data of a province in the central region, the safety, economy, cleaning, efficiency and coordination weight of the provincial low-carbon energy development assessment were calculated as 0.21, 0.18, 0.28, 0.16 and 0.17, respectively. By calculating, the comprehensive index of low-carbon energy development is formed, and the calculation formula is as follows:

\[ A = \sum_{i=1}^{n} X_i K_i \]

In the above equality, \( X_i \) is the weight coefficient of the index, and \( K_i \) is the score of the index, and the value range of \( K_i \) is \([1, 10]\).

In order to evaluate the efficiency of provincial low-carbon energy planning, conventional scenarios and low-carbon scenarios are established. The conventional scenario is not concerned with carbon emission reduction constraints, and the low-carbon scenario is concerned with carbon emission reduction constraints. By comparison, the following conclusions are found.

The comprehensive index of low-carbon energy development continues to rise. In the low-carbon scenario, the low-carbon energy development index is up from 7.0 in 2010 to 8.7 in 2020 and 9.7 in 2030, while 7.7 in 2020 and 8.6 in 2030 in the conventional scenario. This is mainly due to the significant improvement in safety, cleanliness, efficiency and coordination of low-carbon energy policies. Although the development of low-carbon energy will reduce the overall economy of the energy system in the short term, the economic impact will gradually decrease with the improvement of clean energy technology. Figure 3 is the comprehensive index of low-carbon energy development from 2020 to 2030. Figure 4 is the score of each evaluation index in 2020.

![Figure 3. Comprehensive index of low-carbon energy development (2010-2030).](image-url)
Safety indicators: In contrast to conventional scenarios, energy demand will fall slightly in low-carbon scenarios, which means energy supplies is more plentiful.

Economic indicators. In low-carbon scenarios, the proportion of non-fossil energy in energy consumption will increase, and its price will be higher than that of coal, which will reduce the economy of energy supply. Due to environmental taxes and other policies, such as the environmental cost of fossil energy through taxation, the cost of coal production will be increased and the economy will decline significantly.

Cleanliness indicators: Low carbon scenario compared to the conventional situation, greenhouse gas emissions significantly reduces, clean energy in 2020 will reach 15.2% of primary energy which is more than planning objectives, and the proportion of electricity accounts for terminal energy sources significantly increase.

High performance indicators: The energy consumption per unit of GDP in 2020 is 12.3% in low carbon scenario lower than that in 2015, while the conventional scenario is 10.0%. Carbon emissions per unit of GDP fell by 16.2% compared with 2015 in low carbon scenario, while the conventional scenario was 10.0%.

Coordinate indicators: In the low carbon scenario, pollution emissions and energy consumption will drop in the provincial rankings, comparing the neighboring provinces. This index relates to the evaluation results of other provinces. The calculation data are shown in Table I.

Table 1. A comparison of future low-carbon energy development in a province and China.

<table>
<thead>
<tr>
<th></th>
<th>2020 general scenario (province)</th>
<th>2020 low-carbon scenario (province)</th>
<th>2020 general scenario (China)</th>
<th>2020 low-carbon scenario(China)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy consumption (tons of coal)</td>
<td>10936</td>
<td>10679</td>
<td>503000</td>
<td>473000</td>
</tr>
<tr>
<td>Coal (ton coal)</td>
<td>7327</td>
<td>7048</td>
<td>297000</td>
<td>277000</td>
</tr>
<tr>
<td>Oil (tons of coal)</td>
<td>1859</td>
<td>1815</td>
<td>83000</td>
<td>76000</td>
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<tr>
<td>Gas (tons of coal)</td>
<td>328</td>
<td>320</td>
<td>47000</td>
<td>46000</td>
</tr>
<tr>
<td>Non-fossil energy (tons of coal)</td>
<td>1422</td>
<td>1495</td>
<td>76000</td>
<td>73000</td>
</tr>
<tr>
<td>Carbon emission (10,000 tons CO2)</td>
<td>24846</td>
<td>23966</td>
<td>1078919</td>
<td>1006792</td>
</tr>
<tr>
<td>Non-fossil energy accounted for</td>
<td>13.0%</td>
<td>14.0%</td>
<td>14.0%</td>
<td>15.0%</td>
</tr>
<tr>
<td>GDP ($100 million, no change in 2014)</td>
<td>25100</td>
<td>25100</td>
<td>871238</td>
<td>871238</td>
</tr>
<tr>
<td>Carbon emission intensity of unit GDP (tons per million yuan)</td>
<td>0.99</td>
<td>0.95</td>
<td>0.58</td>
<td>0.54</td>
</tr>
</tbody>
</table>
Summary

In this paper, a provincial index system for the assessment of low-carbon energy development is constructed, which consists of three levels: basic energy data, analytical index and evaluative index. Through the construction of the development scenario, the basic energy data are determined, the analytical indicators are measured and the development of low-carbon energy at the provincial level is evaluated from the perspectives of safety, economy, cleanness, efficiency and coordination. The method proposed in this paper is applied to the assessment of low-carbon energy development in a central province. The weight of the specific evaluation index is determined by the analytic hierarchy process and expert opinion method. The findings will underpin government decision-making. The research results of the evaluation method should be used for reference by various provinces.

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References


