Measuring Low-carbon Development Level of provincial construction Industry

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Abstract. In the 13th Five-Year plan, promoting Low-carbon cycle development is proposed. Low-carbon economy has become the key direction. As the pillar industry of national economy, the construction industry contributes obviously to the economic development. And the consumption of energy and the pollution of the environment can not be ignored. Accurately grasping the carbon emission level of the provincial construction industry is critical to making the future development strategy. In the paper, carbon emissions, energy consumption and economic growth of the provincial construction industry are analyzed firstly, then low carbon evaluation index is built to measure low-carbon level of provincial construction industry, at last relevant policy suggestions are put forward accordingly.

1. Preface

China’s economic development has never been the traditional economic development model. It has entered an important stage to high-efficiency, Low-carbon economic development model. In December 2016, on the issuance of the "13th Five-Year" comprehensive energy reduction program", it is said by the state council that the main goals of the "13th Five-Year" is the national energy consumption of per ten thousand Yuan GDP of year 2020 decreasing 15% compared with 2015. Total energy consumption is controlled within 50 million tons of standard coal. Experiment on very-low and nearly-zero energy building construction is proposed especially. Green ecological construction demonstration city should be carried out. However, China is a vast country. The economic development and carbon emission levels of provincial construction industry are different. The provincial low carbon levels should be first grasped. In the measurement of low carbon level, Yujie Lu and others (2012) evaluate the effectiveness and fairness of different carbon emission reduction policy tools in the U.S.[1]. G.Verbeeck (2010) calculate the carbon emission of different types of residential buildings using construction life cycle inventory method [2]. Jianrong Tang and Yexiao Li (2013) construct the department greenhouse gas emission matrix, analyzes the distribution structure of carbon emission in Jiangsu and Zhejiang using 2007 regional economic input and output table [3]. Hu Ying and Dajian Zhu (2015) calculate the direct emissions of carbon dioxide from China's construction industry between 1996 and 2012 using IPCC's carbon emission coefficient method [4].

It is obvious, the energy consumption and carbon emissions of the construction industry have been widely discussed by the foreign scholars. However, considering that the study of low carbon level in provincial construction industry measured by the total energy consumption, the energy consumption structure and the development level of the construction industry has not been searched. This is also the opportunity of this study.
2. Current situation of economic growth, energy consumption and carbon emission of provincial construction industry

2.1 Economic growth status of provincial construction industry
This paper is based on the added value of construction industry in 30 provinces of China during 2005-2014 (Figure 1). Based on 2005, the growth rate of the province after the period is calculated, and then the average of the growth rate is calculated (Figure 2). At the same time, the ratio between the output value of the provincial construction industry and the gross national product of the province during 2005-2014 was calculated to analyze the status of provincial construction industry in regional economic development (Figure 3).

![Figure 1. Provincial construction GDP in 2005-2014](image1)

![Figure 2. Change ratio of provincial construction GDP in 2005-2014](image2)

![Figure 3. Importance of provincial construction industry in local economy](image3)

From Figure 1, it is obvious that provincial construction output is in great different from year 2005 to 2014. Jiangsu Province is the highest and Ningxia Province is the lowest, the former is more 21
times than the latter. From Figure 2, provincial average monthly change rate is different. Among them, the largest one in Tianjin reaches 12%, and the smallest one in Shanghai is 8%. From Figure 3 From Figure 3, importance of provincial construction industry to regional economy is quite different, in which, construction industry in Zhejiang, Beijing, Jiangsu and Chongqing plays an important role in the regional economic development, and contributes more than 30% to the regional economic development. However, construction industry of Hainan Province, with tourism as its main component, contributes less than 10% to the regional economic development.

2.2 Current situation of energy consumption in provincial construction industry

In order to unify the calculation caliber, according to the general rule of energy consumption calculation(GB-T2589-2008) and the energy conversion coefficient in Table 1, the direct energy consumption of the provincial construction industry is converted to standard coal. According to the conversion coefficient of different energy units in Table 2, energy consumption of three construction materials is converted into standard coal. Finally, direct and indirect energy consumption is added to get the total energy consumption of the provincial construction industry calculated by standard coal.(Figures 4 and 5)

| Table 1. | Energy conversion coefficient |
| --- | --- | --- | --- | --- | --- |
| Energy | Raw coal | Gasoline | Kerosene | Diesel | Other Petroleum products | Electric Power |
| Conversion coefficient of standard coal | 0.71 | 1.47 | 1.47 | 1.46 | 0.20 | 1.23 |
| Carbon emission factor | 0.77 | 0.56 | 0.57 | 0.59 | 0.59 | 0.28 |

Note: the unit of electricity is t / 104kwh; All other energy sources are t/t; The unit of carbon emissions is t/t.

| Table 2. Conversion coefficient of different energy units |
| --- | --- | --- | --- | --- |
| Projects | 1GJ | 1t Standard coal | 1kw.h | 1t CO2 |
| GJ | 1.00 | 29.27 | 3.6×10⁻³ | 11.19 |
| Standard coal(t) | 0.03 | 1.00 | 0.1227×10⁻³ | 0.38 |
| Kilowatt hour(kw.h) | 0.278×10⁻³ | 8.137×10⁻³ | 1.00 | 3.106×10⁻³ |
| Carbon dioxide(t) | 0.09 | 2.26 | 0.322×10⁻³ | 1.00 |

Figure 4. Provincial total energy consumption of construction industry in 2005-2014
Through statistical analysis, the total energy consumption of China’s provincial construction industry is increasing year by year, but there are still differences between provinces. From vertical direction of the province, the changing trend is different. For example, Beijing has generally declined, but other provinces showed varying degrees of growth. At the same time, it can be seen from figure 5 that the indirect energy accounts for the total energy consumption of the provincial construction industry about 96%.

2.3 Carbon emission status of provincial construction industry

(1) Calculation of direct carbon emission in provincial construction industry

The emission coefficient method proposed by the Intergovernmental Panel on Climate Change has been used to calculate the direct carbon emissions of the provincial construction industry. Under this method, Carbon dioxide emissions from a primary energy such as raw coal, diesel, gasoline, other petroleum products and the use of secondary energy are added to calculate the direct carbon emissions of the provincial construction industry. See Formula (1)

$$B_m = \frac{12}{44} \sum_{n=2005}^{2014} \sum_{i=1}^{44} E_{mn} \times \lambda_i \quad (1)$$

In which: Bm is the direct carbon emission of the construction industry in M province. Emni represents the physical consumption of i kinds of energy in M province in N year. The carbon dioxide emission coefficient of the ith energy is expressed in λi. The energy type conversion standard coal coefficient used in this paper can be referenced in Table 1[9].

(2) Calculation of indirect carbon emissions of provincial construction industry

According to the availability of data and the particularity of the life cycle of building products, this paper uses the energy theory proposed by Han Yining[5] and others to calculate the carbon emissions of building materials production process. The energy conversion is shown in Table 2. Calculation of carbon dioxide emission of building materials is shown in Formula (2).

$$Q_m = \sum_{n=2005}^{2014} \sum_{i=1}^{111} q_{mi} c_i \quad (2)$$

In which: carbon dioxide emissions from building materials in M province are represented by Qm. qimni represents building material consumption of i kinds of energy in M province in N year. The strength of carbon dioxide released during the construction of the ith building material is represented by Ci to indicate the total energy consumed by the building material per unit of production quality. According to the Formula (3) and the conversion factor in Table 2, the carbon dioxide intensity value of the building material during processing can be calculated.

$$c_i = 0.0894 \times e_i + c_{ei} \quad (3)$$

In which, energy intensity value in the production process of building materials is indicated by ei. The intensity of additional carbon dioxide released during the processing of building materials is
The calculation results are shown in Table 3.

Table 3. Carbon dioxide intensity in the manufacturing process of different building materials

| Building materials | Production energy intensity $e_i (\text{GJ/t})$ | Extra carbon dioxide intensity $C_{ei} (\text{t/t})$ | Production of carbon dioxide intensity $C_i (\text{t/t})$ |
|--------------------|-----------------------------------------------|------------------------------------------------|--------------------------------------------------|
| Steel              | 29                                            | 0.2                                            | 2.79                                             |
| Cement             | 5.5                                           | 1                                              | 1.49                                             |
| Architectural glass| 16                                            | 0                                              | 1.43                                             |

(3) Total carbon emissions of construction industry

The total carbon emissions of the construction industry are equal to the sum of the direct and indirect emissions. Combined with the carbon accounting method above, the total carbon emission of China's 30 provincial construction industries are calculated. (Figure 6)

Figure 6. Total carbon emissions of provincial construction industry in 2005-2014

It can be seen that the total carbon emissions of China's construction industry has increased year by year, but its difference is greater. For example, carbon emissions in Beijing and Shanghai have increased or decreased over the past 10 years, but the total carbon emissions have been reduced. Others are basically increasing, among them, carbon emissions from Hebei, Jiangsu and Shandong are at the forefront, but carbon emissions from Beijing, Shanghai and Hainan are relatively low.

3. Low carbon level measurement in provincial construction industry

(1) Construction of low carbon level measure index of provincial construction industry

The low carbon development level of the provincial construction industry is closely related to its economic development, resource endowment and carbon emission structure. The low carbon level defined in this paper includes two aspects: one is the decrease of carbon emission in the unit production value, and the second is the decrease in energy consumption per unit production value. In this paper, the concept of low carbon economy and value engineering are combined to construct a comprehensive evaluation index of low carbon. See Formula (4)

$$W_i = \frac{WE_i WC_i}{WG_i}$$

In which, the comprehensive low carbon economy in i province is represented by $W_i$. The smaller the $W_i$ value, the higher the output value of the construction industry in i Province, the less energy consumption per unit output value, the lower carbon output per unit output, and the low carbon economy level. When the value of $W_i$ is closer to $e$, it shows that the low carbon level in i province is closer to the national average. The level of economic development in i province is expressed by $WG_i$. The level of energy consumption per unit in i province is expressed by $WE_i$. The level of carbon emission in i province is expressed by $WC_i$. Among them:

$$WG_i = e^{(\frac{\text{GDP}_i}{\text{GDP}_{\text{avg}}})}$$
$$WE_i = e^{\left(\frac{E_i}{\text{E}_{\text{avg}}}ight)}$$
$$WC_i = e^{\left(\frac{CO_{2i}}{\text{CO}_{2\text{avg}}}ight)}$$

In which, the average output value, average energy consumption and average carbon emission value of 30 provinces were expressed by $\text{GDP}_{\text{i}}, \text{E}_i$ and $\text{CO}_{2i}$ respectively. The greater the $WG_i$ value,
the higher the construction output value in i province is higher than the national average output value. When the value of $W_G_i$ equal to e or closer to e, it shows that the construction output value of i province is basically the same as the average output value of the country. The lower the value of $W_E_i$ and $W_C_i$, the lower carbon level in i province is higher than the national average. When $W_E_i$, $W_C_i$ value is equal to e or closer to e, the low carbon level in I province is basically consistent with the national level.

(2) The results of low carbon level measurement in provincial construction industry

According to the Formula (4), the economic growth value, energy consumption and carbon emission values of the provincial construction industry accounting in the last section were combined to measure the index values of the provincial construction industry from 2005 to 2014. (Figure 7)

![Figure 7. Low carbon level index value of provincial construction industry in 2005-2014](image)

From Figure 7, the low carbon levels of the provincial construction industry from 2005 to 2014 are very different, and each province has changed in different ways over the last 10 years. Among them, the low carbon level in Hebei province is the worst and has been in the extensive development mode of high consumption and high carbon emissions. Followed by the Guizhou Province, from the beginning of 2009, as the contribution of the construction industry to the regional economy increases and the low carbon level drops greatly, the construction industry in the province is also showing the development path of high energy consumption and high carbon emissions. Provinces with better low-carbon levels include Jiangsu, Shandong and Guangdong.

4. The research conclusion

In the paper, based on statistical data from 2005 to 2014, economic development, energy consumption and carbon emission of China's provincial construction industry are analyzed firstly. The total carbon emission level of provincial construction industry including indirect carbon emissions is calculated secondly. Then the low carbon level measurement index of construction industry is constructed to measure low-carbon level of provincial construction industry. The following conclusions are obtained.

(1) The economic development level of provincial construction industry and its contribution to regional economy are significantly different. In the decade, Jiangsu, Shandong and Guangdong have the largest total added value. The construction industry in Beijing, Jiangsu and Chongqing contributes nearly 30% to the regional economic development.

(2) Energy consumption and carbon emissions of provincial construction industry are uneven. The provinces with the largest energy consumption include Hebei, Jiangsu and Shandong, with the smallest energy consumption in Hainan, followed by Qinghai and Ningxia.

(3) Low carbon levels of provincial construction also exist significant difference. Hebei and Guizhou provinces have the worst low carbon levels. They have always been in a high consumption, high carbon emissions of the extensive development model. The provinces with the best low carbon levels are Shandong, Jiangsu and Guangdong.

In briefly, low carbon level of provincial construction industry is satisfied, which may be caused by extensive economic development mode unreasonable energy consumption structure, it is necessary to analyze the causes of low provincial carbon levels, and take measure to bring gradually the construction industry into a low-carbon economy.
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