LMDI Model-Based Analysis of Direct Carbon Emission Accounting and Influencing Factors of China’s Building industry

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Abstract: It is generally believed that the building industry is a high-energy and non-environmentally friendly industry. Accounting and analysis of carbon emissions in the building industry is essential for the low-carbon sustainable development of the building industry. This study uses the 2010-2018 China energy consumption data, using the LDMI method to split the influencing factors into four parts: energy intensity, energy structure, economic output (per capita construction GDP) and population size, and proposes low-carbon building industry development. Countermeasures. Studies have shown that all four parts contribute to the carbon emissions of China's building industry.

1. Introduction
The rapid growth of Chinese economy is characterized by strong energy consumption. In 2007, China has surpassed the United States to be the largest emitter of greenhouse gases in the whole world. The Chinese government promised that carbon dioxide emissions peaked in about 2030 and struggle to reach its peak as fast as can at the Paris Climate Conference in 2015. In order to achieve the set emission reduction task, China needs to implement the carbon reduction level in various industries. It is generally believed that the building industry, which is the pillar industry of the national economy, is a typical high-energy and non-environmentally friendly industry, and is closely related to many other industries. On a global scale, the building industry's carbon emissions account for 36% of total emissions, while more than 95% of China’s existing building area is high-energy buildings. At the same time, according to the relevant climate change report issued by the IPCC, the building industry is the industry with the most energy-saving and emission reduction potential. Therefore, accounting for the carbon emissions of the building industry and the analysis of the influencing element are crucial for the low-carbon sustainable development of the building industry.

2. Literature review
At present, domestic research hotspots focus on direct carbon emissions, accounting and forecasting of indirect carbon emissions, and decomposition analysis of influencing factors. Song[1], Zhang[2], Guo[3] respectively used LDMI method to conduct factor decomposition study on the greenhouse gas emission of energy consumption in China, and found that energy intensity, economic growth and economic structure were the main factors affecting carbon emission. Du, Lu, Feng, Bai[4] used LMDI model to decompose the elements into direct emission ratio, energy consumption per unit
value, value creation effect, indirect carbon emission intensity and output scale effect. They found that output scale effect was the largest positive factor of carbon emission in the building industry, and value creation effect had passive effect on green-house gas emission, but the effect was not ideal. Wang et al. [5] used the grey system theory to predict that the carbon emissions of the building industry in Fujian Province will reach 8.4 million tons in 2020, which has not yet reached its peak. Song [6] used LMDI index decomposition method to quantitatively analyze the impact of carbon emission intensity, energy structure effect, energy intensity effect and indirect carbon emission effect on China's building industry carbon emission intensity. It is found that the carbon emissions of China's building industry have maintained an overall upward trend, and indirect carbon emissions have remained above 92% over the years. Qi [7] et al. used the economic input-output method to establish a complete carbon footprint model for the building industry and calculate direct and indirect carbon emissions. By applying Kaya identity, the factors affecting the total direct carbon emissions of the building industry are decomposed into energy structure effect, energy intensity effect, industrial scale effect and economic output effect, and it is found that the carbon emission from the building industry is significantly hidden. Liu [8] et al. used STIRPAT model to make a quantitative analysis of the factors that affected the carbon emission of public and residential buildings in Guangzhou from 2006 to 2014. The research showed that the increase of public building area and the tertiary industry had the greatest impact on the carbon emission of public buildings, followed by the unit consumption of residential buildings, and the least impact on residents' consumption level.

In view of the fact that the real estate industry is the pillar industry of China's economy, the demographic factor is very important. This paper refers to Gao Ying's model [9] in studying the carbon emissions from Tianjin transportation industry. The LDMI decomposition method is used to influence the energy structure, energy consumption intensity and per capita energy of China's building industry. Decomposition analysis of GDP and population factors in the building industry.

3. Definition

Construction [10] refers to the scope covered by China's input-output table, including housing and civil engineering construction, construction installation, construction decoration, and other construction industries. The housing and civil engineering construction includes housing engineering, railways, roads, tunnels and bridge engineering construction, water conservancy and port engineering construction, industrial and mining engineering construction, wiring and pipeline engineering construction, and other civil engineering construction; Other construction industries mainly include engineering preparation and construction equipment services.

Carbon emissions in the building industry refer to the sum of greenhouse gas emissions generated by the building and its related building materials production and transportation, construction and demolition, and operation stages, expressed in terms of carbon dioxide equivalent.

4. Carbon emission accounting of China's building industry

4.1 measurement method

Coal, diesel and electricity account for a large proportion of energy consumption in the building industry, which is the main source of carbon emissions in the construction sector. The 2006 IPCC national greenhouse gas inventory guidelines describe three methods for estimating emissions from fossil fuel combustion. [11] (1) emission estimates of all combustion sources can be calculated based on the amount of fuel burned and the average emission factor; (2) emissions from combustion are estimated using fuel statistics similar to method 1, but with a specific national emission factor instead of the default factor of method 1; (3) the calculation of carbon emissions will, where appropriate, use detailed emission models or measurements, as well as individual factory-level data. This paper chooses Method 1 to calculate. The formula for the calculation is as follows:

\[ C = \sum A_i F_i K_i \]
Where: $C$ —— carbon emissions from energy consumption

$A_i$ —— consumption of $i$-type energy for terminal energy consumption

$F_i$ —— $i$-type energy standard coal reference coefficient

$K_i$ —— the energy emission coefficient of the $i$-type energy, which refers to the amount of heat released by fossils through combustion and their corresponding carbon content.

### 4.2 Accounting of Carbon Emission of Energy Consumption in Building Industry

#### 4.2.1 Total Carbon Emission of Building Industry

Among the terminal energy consumer goods, gasoline, diesel and kerosene have large differences in carbon emissions from other fossil energy sources. Among them, the carbon emission caused by gasoline consumption is the fastest growing, from 1.69 million tons of carbon in 2010 to 3.76 million tons in 2018; coal fluctuated from 2010 to 2018, reaching a peak of 4.93 million tons in 2016; diesel The carbon consumption consumed has a steady trend, reaching 4.67 million tons in 2018, an increase of 1.59 million tons from 2010; the carbon consumption of electricity and kerosene consumption remained stable. Overall, the carbon emissions of China's building industry in 2010-2018 generally showed an upward trend.

#### 4.2.2 Analysis of Carbon Emissions per Capita Building Industry

It can be seen from Figure 2 that from 2010 to 2018, the per capita carbon emissions of Chinese building industry increased from 65.04kg carbon/person to 131.89kg carbon/person, which doubled. In the past eight years, except for the decline in 2012-2013, the other years have maintained a relatively rapid growth.

#### 4.2.3 Analysis of Carbon Emission Intensity in Building Industry

As shown in Figure 3, from the eight years of 2010-2018, the overall carbon emission intensity of China's building industry showed a downward trend, from 0.011kg carbon per 10,000 yuan in 2010 to 0.008kg per 10,000 yuan in 2018.
5. Research of Elements Influencing carbon emissions in Chinese building industry

5.1 LMDI decomposition method

This paper selects the LMDI decomposition method to decompose and analyze the energy structure, energy consumption intensity, per capita building industry GDP and population factors that affect China’s building industry carbon emissions.

\[ S_i = \frac{E_i}{E}, \quad I = \frac{E}{Y}, \quad R = \frac{Y}{P}, \quad F_i = \frac{C_i}{E_i} \]

| \( i \) | Types of energy | \( S_i \) | The energy structure | \( E_i \) | Type i energy consumption | \( E \) | Total energy consumption | \( I \) | Energy intensity | \( Y \) | Construction industry gross production value | \( R \) | Per capita construction GDP | \( P \) | population | \( F_i \) | Carbon emission coefficient of the i-th energy | \( C_i \) | Carbon emissions from the i-th energy consumption |
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Table 1

- Unit: 10,000 tons
- Note: That is, the ratio of the i-th energy consumption to the total energy consumption

Figure 3. China's building industry carbon intensity in 2010-2018
Where:  

\[ C = \sum_{i=1}^{n} C_i = \sum_{i=1}^{n} \left( \frac{E_i}{E} \times \frac{C_i}{E_i} \times \frac{Y}{P} \times \mu \right) = IRP \sum_{i=1}^{n} S_i F_i \mu X \]

\[ \Delta C = C^T - C^0 = I^T R^T \sum_{i=1}^{n} S_i^T F_i^T - I^0 R^0 \sum_{i=1}^{n} S_i^0 F_i^0 = \Delta C_I + \Delta C_S + \Delta C_R + \Delta C_P + \Delta C_F \]

\[ \Delta C_I = \ln \left( \frac{I^T}{I^0} \right) \sum_{i=1}^{n} \left( \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \right) \]

\[ \Delta C_S = \ln \left( \frac{S^T}{S^0} \right) \sum_{i=1}^{n} \left( \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \right) \]

\[ \Delta C_R = \ln \left( \frac{R^T}{R^0} \right) \sum_{i=1}^{n} \left( \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \right) \]

\[ \Delta C_P = \ln \left( \frac{P^T}{P^0} \right) \sum_{i=1}^{n} \left( \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \right) \]

\[ \Delta C_F = \ln \left( \frac{F^T}{F^0} \right) \sum_{i=1}^{n} \left( \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \right) \]

5.2 Analysis of Elements Influencing China's Construction Carbon Emissions

In line with the above decomposition model, the contributions of various influencing elements on the greenhouse gas emissions of the Chinese building industry in 2010-2018 are calculated. As shown in Table 2.

Table 2: LMDI Analysis of Energy Carbon Emissions in China's Construction Industry

| Year | Energy intensity effect | Energy structure effect | Economic output effect | Population size effect | Total effect |
|------|------------------------|------------------------|-----------------------|-----------------------|-------------|
| 2010 | 0.00                   | 0.00                   | 0.00                  | 0.00                  | 0.00        |
| 2011 | -38.41                 | -46.22                 | 191.46                | 4.03                  | 110.86      |
| 2012 | 65.24                  | -69.63                 | 388.93                | 8.87                  | 393.41      |
| 2013 | -144.80                | -53.97                 | 552.42                | 14.01                 | 367.66      |
| 2014 | -241.66                | -79.48                 | 690.50                | 18.74                 | 388.1       |
| 2015 | -226.98                | -98.14                 | 822.51                | 24.89                 | 522.28      |
| 2016 | -184.23                | -24.14                 | 861.96                | 30.70                 | 943.56      |
| 2017 | -235.66                | -107.47                | 944.35                | 37.50                 | 638.72      |
| 2018 | -300.78                | -190.62                | 1040.46               | 42.96                 | 592.02      |

(1) Analysis of energy structure factors: From 2010 to 2018, the energy structure will promote the overall performance building industry carbon emissions in China.

(2) Energy intensity factor analysis: During the study period, energy intensity promoted the overall performance of China's building industry carbon emissions.

(3) Analysis of economic output factors: economic gain also has a significant role in boosting greenhouse gases emissions in the building industry.
(4) Analysis of population size: The increasing population size has a very large promotion of carbon emissions in the building industry, and this positive effect continues to increase. With the advancement of urbanization, the rural population and a large number of transfers, resulting in increased housing, factories and public buildings, etc., have gradually increased the pressure on greenhouse gases emissions in the building industry.

6. Conclusion and Deficiency

As the process of urbanization continues to deepen, the green-house gas emissions of the building industry will continue to grow, but the acceleration of carbon emissions in China's building industry has gradually slowed down. This shows that in recent years, China has promoted low-carbon and environmentally-friendly building materials and actively recycled buildings. Waste, the implementation of prefabricated buildings and other measures have effectively reduced the direct carbon emissions of the building industry. However, the building industry has the characteristics of "low surface carbon and implied low carbon". Over 90% of the carbon emissions in the building industry come from indirect carbon emissions. This paper only studies the influencing elements of direct green-house gases emissions in Chinese building industry. In the future work, attention should be focused on indirect carbon emissions.

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