Analysis on building industry CO_2 emission in Shanghai

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Abstract. With the economic development in Shanghai, a lot of energy has been consumed in the building industry, and is accompanied by a great amount of carbon emissions. Based on the data of energy consumption in the two stages of the building materials production and construction process in Shanghai, a calculation model of CO_2 emissions was created, total CO_2 emissions have been evaluated during recent ten years, and CO_2 emissions influencing factors was identified in each stage. The research results show that CO_2 emissions in the stage of building materials production, account for more than 90% of total CO_2 emissions, mainly traced from cement, iron and steel industry, and have greater potential for energy conservation and emissions reduction.

1 Introduction

With the rapid development of urbanization in China，the total of building energy consumption and the intensity of energy consumption continues being increasing, greenhouse gas emissions are also rising. According to statistics, about 40% of the energy consumed in the world each year are related to the building industry, and CO_2 emissions from the construction sector account for about 36% of global carbon emissions[1]. It is anxious to reduce carbon emissions in the building industry. In 2016, the State Council issued the "Thirteenth Five-Year Plan" for the control of greenhouse gas emissions, and further proposed the total energy consumption and carbon emissions control targets: By 2020, the CO_2 emissions per unit of GDP will decline by 18% from 2015, and the total carbon emissions will be controlled effectively. The CO_2 emissions calculation model is established, which is an essential foundation for reducing carbon emissions and analyzing the CO_2 emissions in the building industry so as to implement targeted carbon emissions reduction measures.

In recent years, some results have been obtained since scholars did relevant researches on building carbon emission. In the past studies, some literature research on CO_2 emissions from the life cycle of the building of all stages, including building materials mining and production, construction, building use and maintenance and recycling stage [2]. Some literature compares CO_2 emissions from different building types and analyses it. However, from a macro perspective, only a few studies have been conducted on total CO_2 emissions during the building materials production and construction process stage.

In this paper, the calculation boundary of CO_2 emissions in the building industry is determined firstly, following available data, concise calculation model and the scientific calculation method. Total CO_2 emissions can be divided into two stages: the building materials production and construction process. Calculation model of CO_2 emissions has been created and emission factors have been identified. CO_2 emissions of the building industry have been evaluated in Shanghai yearly.

Key factors affecting carbon emissions are to be identified and basic data are to be provided for energy conservation and emission reduction in the building industry in Shanghai.

2 Study method

2.1 Carbon Emission Factor

Carbon Emission Factor, which is an important parameter used to signify each kind emission characteristics of energy of greenhouse gas, indicates the production of CO_2 accompanied by energy consumption per unit of mass [3]. The carbon emission factor is the unit quality of sum of the amount of greenhouse gas emitted from each phase to CO_2. The International Energy Agency (IEA) unifies the emissions of various types of greenhouse gas into carbon dioxide equivalent (CO_2-eq) for quantitative analysis of carbon emissions[4].

2.2 Carbon Emission Calculation Boundary and Stage

Due to the depth of research and also inaccessibility of data, it cannot be fully calculated the CO_2 emissions from two stages of building materials production and construction process. Thus, in building materials production stage, four main materials are regard as calculation objects, and the total energy consumption is used as to calculate in construction process stage.

3 Carbon emission calculation model

CO_2 emissions of the building industry mainly come from two major stages, the building materials production and the construction process. The carbon emissions model proposed being based on "Volume = activity data × emissions". After obtaining relevant data from sub-activities, energy consumption of sub-fuel species and corresponding emission factors, the final summation will be done [5], the calculation model is as following.

$$E_c = E_{cm} + E_{ce} \quad (1)$$

Comments: E_c indicates the total of CO_2 emissions. E_{cm} indicates the CO_2 emissions in the stage of building materials production. E_{ce} indicates the CO_2 emissions in the construction process.

3.1 Calculation Model of CO_2 Emission in the Stage of Building Materials Production

There are many types of building materials, due to the difficulty of time and statistics, it is impossible to count all kinds of building materials completely, and the carbon emission factors of materials are affected by many aspects, such as the scale of building materials manufacturers and production technology. The calculation of CO_2 emissions in building materials must take into consideration the recyclable factor of building materials. Although glass and wood can be recycled in part, the recycled glass is no longer part used in building generally. Therefore, glass and wood recyclable factors are not considered in calculation. Recyclable factor of renewable materials has shown in Table 1.

Table 1. Recyclable materials recovery factor[6].

Materials	Factor
Steel	0.35
Rebar	0.40
Aluminum	0.95
Plate glass	0.80
Wood	0.10

The CO_2 production stage of building materials is mainly from the energy consumption (coal, diesel, etc.), the decomposition of raw materials (decomposition of limestone, etc.), and the energy workers (energy, etc.). The calculation process can be performed according to the formula (2).

$$E_{cm} = \sum_{i}^{n} p_i \times q_i \times (1 - \alpha_i) \quad (2)$$

Comments: α_i indicates the recovery factor of building materials. p_i indicates the emission factor of building materials. q_i indicates the consumption of building materials.

Table 2. The consumption of major building materials in Shanghai over the years.

Year	Cement（10^8 t）	Steel（10^8 t）	Aluminum（10^4 t）	Glass（10^4 t）
2006	19.10	8.87	16.17	58.70
2007	18.88	9.74	12.39	53.70
2008	19.26	11.26	15.67	58.90
2009	20.62	12.63	17.59	64.30
2010	21.63	13.65	19.29	65.30
2011	23.25	14.63	20.96	83.20
2012	21.12	15.23	52.52	98.10
2013	21.58	15.80	37.76	53.70
2014	22.86	16.78	40.12	95.10
2015	17.39	15.08	36.49	93.50

Table 3. Carbon emission factor in major building materials production stage.

Materials	Unit	Emission factor
Rebar	tCO_2/t	2.03
Cement	tCO_2/t	0.70
Aluminum	tCO_2/t	1.22
Glass	tCO_2/t	1.40

Steel is one of the important materials for building production. Its carbon emissions are related to the production process closely. In the steel-making process, carbon emissions are primarily caused by energy consumption and combustion. Although steel is a high-carbon emissions building material, the recovery rate of steel is high relatively. Therefore, the degree of steel impact on the environment needs to consider the steel recycling rate generally. Rebar, which is recovery in reinforced concrete, is relative difficult and the recovery factor is 0.4. The recovery rate of Merchant steel and Die steel is superior, the recovery factor can be as high as 0.9, average calculation is taken as an average of 0.4.

There are three main cement manufacturing processes: wet rotary kiln, vertical kiln and new dry process. Due to the increasing proportion of new dry process, the results of the new dry process technology are used as reference. According to relevant studies, 50% of carbon emissions come from carbonate decomposition during cement production, 40% from fuel calcinations, and indirect emissions account for 10% of total cement carbon emissions [7]. Therefore, only the production of cement is regard as the calculation directly.

3.2 CO_2 emission calculation model during construction stage

From the perspective of energy statistics system in China, the energy consumption of new construction, existing building alteration. And building demolition is all included in the energy consumption of building industry. In addition, transportation energy consumption of the building materials and construction waste are related to construction activities. It also included in the energy consumption of the building industry. Therefore, the energy consumption of the building industry is utilized to signify energy consumption in construction process[8], and energy consumption is calculated as the formula (3).

Depending on the Energy Balance Sheet from "China Energy Statistical Yearbook" of the past years, "Shanghai Statistical Yearbook", "Shanghai Energy and Environment Statistical Yearbook in 2016", and "Shanghai Industrial Energy Transportation Statistical Yearbook in 2009", the energy consumption of major building materials during 2006 - 2015 is 1.72, 1.79, 1.85, 2.11, 2.17, 2.11, 2.13, 2.14, 2.06, and 2.18 million tce.

The calculated energy consumption is summarized and converted according to the carbon emission factors of fuel type used. Finally, the CO_2 emissions during the construction process are calculated, as the formula (3). According to relevant literature, the CO_2 emissions coefficient (unit: tc /tce) of the complete combustion of 1 ton standard coal: The National Energy Research Institute of the National Development and Reform Commission recommends value is 0.67. The value is 0.68 in Japan Institute of Energy Economics, and the reference value of the US Department of Energy Information Agency is 0.69. This paper calculates value is 0.68.

$$Q_c = Q_{ct} + Q_{ce} = \sum_i n_i k_i + \sum_j m_j k_j \tag{3}$$

$$E_c = Q_c \times \beta \tag{4}$$

Comments: Q_c indicates energy consumption during construction. Q_{ct} indicates energy consumption during transportation. Q_{ce} indicates energy consumption during construction process. n_i indicates consumption of fuel for transportation. k_i indicates standard coal conversion factor of fuel for transportation. m_j indicates the energy consumption of construction equipment. k_j indicates the standard coal conversion factor of construction equipment. β indicates the standard coal carbon emission conversion factor.

As shown in Figure 1, the sum of emissions in building materials production and construction process stage indicate that the change of CO_2 emissions in the building industry of shanghai. The results indicate that CO_2 emissions increased from 33.56 to 46.02 million tons from 2006 to 2015.

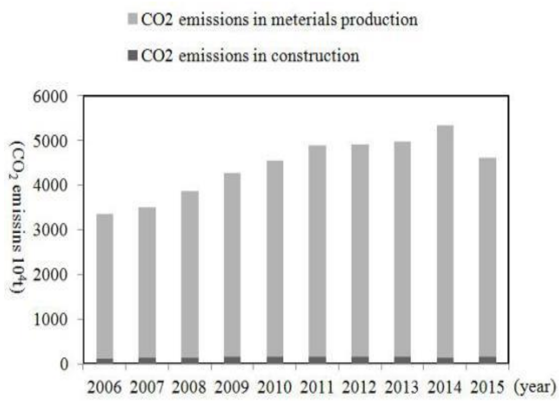

Fig. 1. Total CO_2 emissions over the years in Shanghai.

4 Results analysis

The result show that Shanghai has a large amount of energy for construction and CO_2 emissions. In 2015, the energy for building construction in Shanghai reached 14.84 million tce, accounting for 12.85% of total terminal energy consumption in Shanghai and 46.02 million tons CO_2 emissions for construction process. The rapid growth of energy consumption in building , as the primary industry, has led to the rapid growth of total energy consumption in recent years in Shanghai. Owing to the fact that continued growth of the construction scale in recent years, the production energy consumption of the unit products of building materials has been declining year by year along with the improvement of production technology. In 2015, Shanghai's housing construction area was 3660 million m^2, which was nearly 1 time higher than in 2006, as showed in the Figure 2. Comprehensive energy consumption per unit product of steel and cement decreased by 8.7% and 11% respectively compared to 2006. A continuous increase in the construction of energy consumption, and CO_2 emissions continue to rise on account of the growth rates of the construction scale far exceeds the speed of the decline in construction energy consumption.

CO_2 emissions per unit construction area ranged from 0.21 to 0.12 m^2/tons during 2006 - 2015. Because continuous optimization of construction technology and processes, upgrading of technical equipment and continuous innovation of technologies, as showed in the Figure 3.

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It is significant that controlling construction energy consumption for achieving energy conservation and emission reduction. As China's urbanization construction enters a new phase, further changes have taken place in the urbanization of China. The construction of large-scale residential, buildings, and commercial buildings has come to an end. The problem of absolute shortage has also been eased. Therefore, China should gradually improve its infrastructure in the future, slow down its construction, and slightly reduce its basic construction scale.

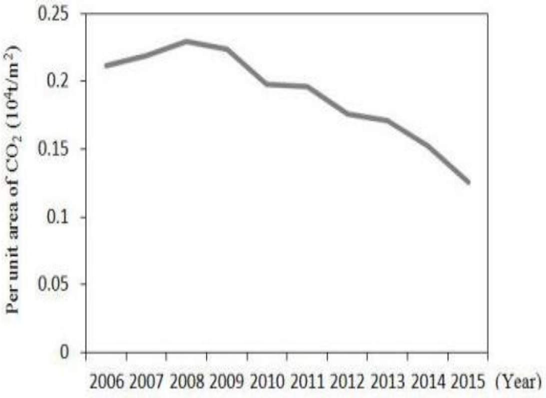

Fig. 2. Building construction area in Shanghai.

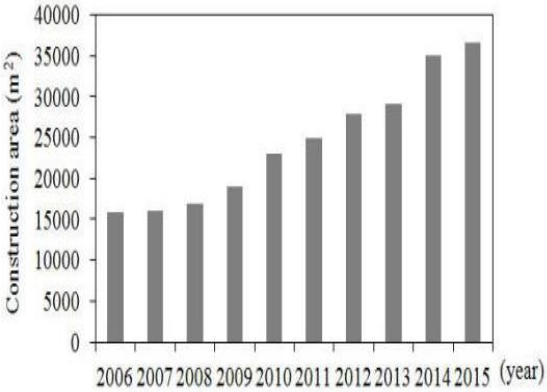

Fig. 3. Per unit area of construction carbon emissions.

5 Conclusion

The two stages of CO_2 emissions from the building industry have been calculated in this paper. The research results show that CO_2 emissions in the production stage of building materials are dominating, while the proportion of construction process stage is insignificant. The energy consumption of building materials in the cement industry, iron and steel industry account for a large proportion of CO_2 emissions, account for more than 90% of total CO_2 emissions, and there is a huge potential for energy conservation and emission reduction. Built on statistical data, the CO_2 emissions from the macro-building industry are calculated year by year. CO_2 emissions controlled in the building industry will be greatly significant to achieve the goal of energy conservation and CO_2 emission reduction in China. The scale of construction should be controlled, and the building construction speed should be reduced also, and the energy saving technology should be employed to reduce the CO_2 emissions.

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