WEP Warwick Evans Publishing

Transactions on Engineering and Technology Research
ISSN: 2960-1797, eISSN: 2960-2246 | Volume 4
ACEGE 2024

Research on Carbon Emission of Green Building in the Full Life Cycle

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Abstract. Due to the increase in carbon emission in the past two decades, especially the construction industry, people's awareness of energy conservation and emission reduction has increased. Therefore, green buildings have gradually prevailed in the construction field and entered China's construction market. This paper is mainly to study the carbon emission on the full life cycle of green buildings. At the beginning, starting from the concept of green buildings, green buildings are divided into resource-conserving type and environment-friendly type. And according to the decrease in carbon emission, green buildings are divided into one-star, two-star and three-star. Through the Person Coefficient Method and Principal Component Analysis (PCA) method. The factors that affect green buildings carbon emission are mainly in the construction operation stage and the preparation stage. Comparing advantages and disadvantages of different methods, the Carbon emission factor method using in different stages is the most suitable method to calculate carbon emission. Finally, according to the proportion of carbon emission at different stages, the corresponding emission reduction policies are proposed. In the context of the "dual carbon", the researches of energy conservation and emission reduction are getting deeper and deeper, and carbon peaking and carbon neutrality are achieved at all stages of the construction industry.

Keywords: Full life cycle; Green Building; Carbon Emission.

1. Introduction

In recent years, global warming has become increasingly serious, and the emission of greenhouse gas have increased year by year. Among them, the construction industry consumes a lot of natural resources, and a large amount of greenhouse gases are released in all stages of design, material production, construction, operation and maintenance, and abandonment. The whole process of carbon emission accounts for about 50.6% of the nationwide carbon emission [1]. The attention of people to carbon emission has increased year by year, so they introduce the concept of green building. Green building can save resources, reduce pollution, protect the environment, provide a healthy and efficient living environment, and realize the peaceful coexistence of people with nature. Green building is the main mean to reduce carbon emission in the construction industry. In the first half of 2022, the construction ratio of green buildings reached 90%, and established the corresponding evaluation system [2].

In the context of "dual carbon", researches on carbon emission have gradually increased. Peng [3] analyzed the carbon emission at the construction stage and studied the distribution of carbon emission during the construction process. Xu et al. [4] established a new method of refined carbon emission indicators to reduce energy consumption in the process of building operations. The construction process has a pivotal impact on carbon emission at all stages, so it is particularly important for the research of carbon emission for green building throughout the cycle. Based on the above background, this article will introduce the development process of green building and the relevant requirements of green building, including the concepts of stars and carbon emission. Based on the full life cycle, the correlation analysis of the carbon emission factors are summarized, and this article uses the Carbon emission factor method to compare the carbon emission of green buildings and ordinary buildings, and emission reduction policies are proposed.

2. The Concept of Green Building

2.1. Development Process

The trend of green building originated from the two world energy crises in 1970. The outbreak of the oil crisis has aroused people's attention to the reduction of energy [5]. Therefore, many international environmental organizations have been formed, and the concept of "ecological building" has also been led to the pioneer of green building. In 1993, the 8th Architects Conference in the World set off a wave of green building. In the context of the world environment crisis, green buildings gradually developed in the construction industry pursuing the sustainable development of cities [5]. Since the release of the first edition of *the Green Building Evaluation Standards* in 2006, green buildings in China have gone through scratch, from less to more. As the end of 2023, the total green building areas of China reached 11.85 billion square meters [1].

2.2. Related Requirements for Green Building

Green building refer to the harmony between man and nature during the full life cycle of production, construction, maintenance and demolition. Its requirement is that it does not cause pollution to the ecological environment during the design and production and materials collection process, and has rare energy consumption. During the abandoned stage, the building is also required to have less pollution caused to the environment, and most of the materials can be reused [6]. Green buildings are divided into resource-conserving type and environment-friendly type. The core of resources-conserving is to save resources and improve energy utilization rates, such as new wall materials, green concrete and insulation materials. The environment-friendly type is to realize the peaceful coexistence of man and nature, and respect the laws of nature, such as waterproof and closed materials and air purification materials [6]. The stars of green buildings are divided into one-star, two-star and three-star level. The higher the star level, the higher the amount of carbon emission, the highest level is the three stars [1]. The green building star evaluation system mainly comprehensively evaluates the safety and durable, health and comfort, convenience of life, resource conservation and environmental livability [7]. Its detailed scoring system is shown in Table 1.

Table 1. Green Building Evaluation Score [7]

Items	Control item	Scoring items					Bonus items
		Safety and durable	Health and comfort	Convenience of life	Resource conservation	Environmental livability	
Symbol	Q_0	Q_1	Q_2	Q_3	Q_4	Q_5	Q_A
Evaluation full score	400	100	100	100	100	100	100

The total score of the evaluation of green buildings is calculated by Eq.1.

$$Q = (Q_0 + Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_A)/10 \quad (1)$$

When the total score of green buildings is 60 points, 70 points, and 85 points, it will be rated as one-star, two-star, and three-star [7].

3. Analysis of Carbon Emission of Green Building in the Full Life Cycle

Green buildings have reduced carbon emission to a certain extent, so the emergence of green building has aroused widespread attention. Building carbon emission includes many greenhouse gases, of

which carbon dioxide emission is the highest [1]. Because the every stages of the building have a very crucial impact on carbon emission, studying the carbon emission of the green building on the full life cycle is particularly important.

3.1. Analysis of the Correlation Factors of Green Building Carbon Emission

In order to perform energy conservation and emission reduction of the full life cycle of the building, this article choose to take green buildings as an example to analyze the main factors that affect their carbon emissions. There are two main methods for the correlation factors of the influencing factors of green building carbon emission. The first method is the Person coefficient method, which quantitatively describes the degree of correlation of the linear relationship between variable interunciation. Through this method, not only is carbon emissions and its influencing factors related, but also have correlations between the influencing factors [2]. The second method is Principal Component Analysis (PCA) method. By extracting a new variable with a large amount of information, the mutual influence between variables is removed. The extracted new variables are sorted at the contribution rate, and the correlation between the analysis and the original influencing factors will be analyzed in turn. Based on this, the main influencing factors of green building carbon emission can be analyzed. The most important impact on the carbon emission of green building is the factors in the construction stage of the building. The second main impact is the factors in the material production stage of the building [2].

3.2. Carbon Emission Calculation Method

In order to reduce the carbon emission of the building more efficiently, this article finds the appropriate method to calculate the carbon emission of ordinary buildings and green buildings, so as to find the advantages and disadvantages of green buildings in emission reduction. At present, the mainstream methods of calculating carbon emission include Carbon emission factor method, Measurement method, Material analysis method, and Input-output method. Among them, the Carbon emission factor method, also known as the Carbon emission coefficient method, is currently the most commonly used carbon emission calculation in worldwide. This method is based on active data. By statistical analysis of the consumption of each energy, carbon emission are multiplied with emission factors. The Measurement method is to measure the carbon dioxide concentration and flow in the air by setting up related detection equipment near the emission source. The Material analysis method is based on the quality and composition of the building in and out of the material. The Input-output method is based on the needs of different industries, establishes input-output tables, and uses linear models to obtain final output. The advantages and disadvantages of each method are shown in Table 2. According to Table 2, the carbon emission factor method is the best choice for calculating carbon emission.

Table 2. Comparison of measuring the amount of emission [8]

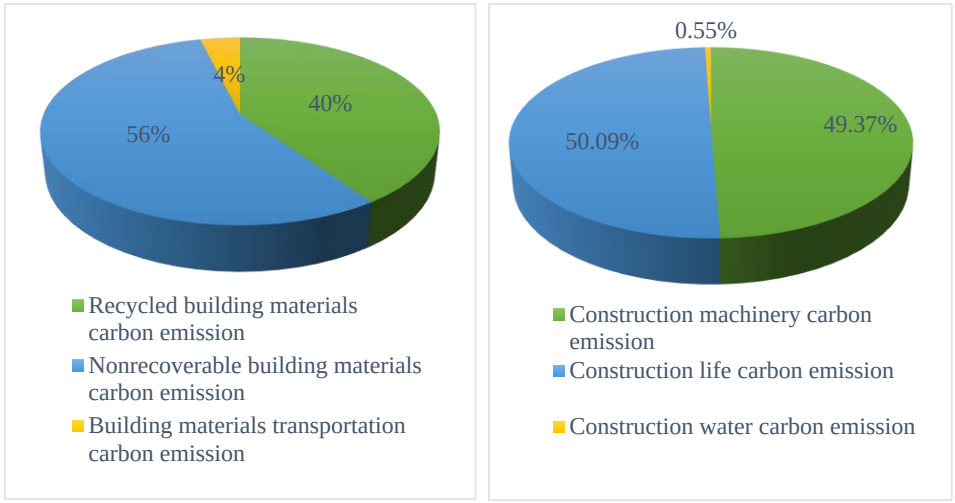
Method	Carbon emission factor method	Measurement method	Material analysis method	Input-output method
Advantages	Simple calculation; wide range of application.	Accurate and reliable data; problems can be found in time.	Simple calculation; reliable data.	Direct and indirect carbon emission combination.
Disadvantages	Accuracy is difficult to guarantee.	High cost and large workload; limited detection and application scope.	High requirements for the whole process; many limitations.	Large workload and calculation errors.

There are two different calculation methods when calculating the carbon emission with carbon emission factor method in the full cycle. The first method is a relatively conventional method. It is calculated according to four stages of material production, construction, operation, maintenance and abandonment [1, 2, 9, 10]. The second method is to divide carbon emission into water carbon emission, electrical carbon emission, and mechanical equipment carbon emission to obtain total carbon emission in calculation [8]. The first method is more accurate and easier to record related data. The second method is more cumbersome, and information collection is more difficult. Therefore, the first method is more applicable.

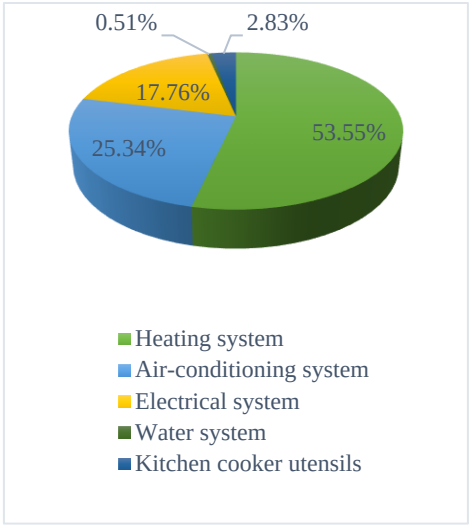
Adopting the method selected in the above process, the calculation of carbon emission for ordinary buildings and green buildings is found that the carbon emission of the two in the materials production, construction and abandonment stage of building are not large. The energy-saving effect of green buildings is mainly reflected in the operation of the building [8, 10].

4. Emission Reduction Analysis of Green Building

Green buildings adopt a large number of green energy-saving technologies, mainly reflected in the protection structure, heating and air conditioning system, lighting equipment and so on. For example, the external protection structure system with ultra-low heat transfer coefficient is used to fully replace the fresh air system, thus reducing carbon emissions [8].



(a) Building materials production stage (b) Construction and abandonment stage



(c) Operation and maintenance stage

Figure 1. The proportion of carbon emission in the full cycle [9]

Fig. 1 is the proportion of carbon emission in the full life cycle of the green building. In the materials production stage of the building, under the premise of ensuring safety, the amount of recyclable building materials is increased, and the dosage of concrete, ceramics and reinforcement is reduced [8, 9, 11]. During the construction stage, the relevant departments can minimize the transportation distance, arrange transportation batches reasonably, increase the awareness of energy conservation of construction personnel, and use solar power generation to reduce power consumption [8, 9, 11, 12]. In the operation and maintenance stage, the relevant departments can use more clean energy, low-consumption systems, excellent peripheral protection systems and insulation materials [12-14]. During the abandoned demolition stage, it is similar to the construction stage, and the utilization rate of recyclable materials must be increased [8, 9, 11].

5. Conclusions

This paper mainly studies the carbon emission of the full life cycle of green buildings, and obtains the following main conclusions:

(1) Green buildings are gradually prevalent in our country. Green buildings are divided into resource-conserving type and environment-friendly type, and are divided into one-star, two-star and three-star level on the star level.

(2) Green building construction operation and materials production phase have the greatest impact on carbon emission. Calculating carbon emission in the Carbon emission factor method is the best calculation method.

(3) During the materials production stage, it is mainly to control the amount of non-recyclable materials and the energy consumption of the construction site during the construction and abandonment phase, and improve the environmental awareness of the construction personnel. The carbon emission in the operation and maintenance stage are large. Additionally, the companies should enhance the function of the outer surrounding system.

(4) In the research of carbon emission in the full life cycle of green buildings, there is no technology to fully achieve zero carbon emission at each stage. In the future, low-carbon is the main theme, and energy-saving and emission reduction are also the top priority of the construction industry. Therefore, the research on building carbon emission will become more and more detailed, and the emission reduction policies will gradually deepen, thereby achieving carbon neutrality and zero emission at all stages of the building.

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