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Optimization Methodology of ESGB on Weights, Evaluation Rating, and Calculation of Carbon Emissions

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Abstract: To cope with climate change, the Chinese government took the lead in advocating the aim of a Carbon peak by 2030 and carbon neutrality by 2060. In China, the total carbon emission of the whole construction process in 2020 was about 5.08 billion tons of carbon dioxide (CO_2), accounting for about 50.90% of the national carbon emission. Consequently, researchers come up with a series of standard assessments for green building optimization measures. Through analysis and comparison of Leadership in Energy and Environmental Design (LEED), WELL Building Standard (WELL), Building Research Establishment Environmental Assessment Method (BREEAM), and Evaluation Standard for Green Building (ESGB) standards, this study will draw conclusions on optimizing ESGB in terms of weighting, evaluation rating, and carbon emission calculations.

Keywords: LEED; WELL; BREEAM; ESGB; Green building; Optimization; Building life cycle management system

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1. Introduction

1.1. Research background

In the context of global warming, environmental deterioration, frequent natural disasters, and other ecological problems are becoming increasingly prevalent. As a result, environmental governance, particularly the reduction of carbon emissions, has become crucial. According to the 2022 China Building Energy Consumption and Carbon Emissions Research Report, carbon emissions from the construction sector accounted for 50.9% of the total emissions. This paper summarizes the evaluation criteria and scoring methods of LEED (U.S.), BREEAM (U.K.), WELL (U.S.), and China's green building standard evaluation system.

1.2. Global green building rating tools

This paper analyzes the weights, evaluation ratings, and carbon emission calculations for LEED, WELL, and BREEAM, and proposes optimization measures for ESGB. Moreover, the author has reviewed and visually analyzed both domestic and international studies related to the purpose and significance of this research, focusing on its direction and theoretical framework. The timeline of the Green Building Evaluation Criteria is shown in **Figure 1**.

1.2.1. The Leadership in Energy and Environmental Design (LEED)

The Leadership in Energy and Environmental Design (LEED) rating system was developed in the US in 1998 by the US Green Building Council (USGBC). LEED was fit for diverse types of buildings. Each of these schemes measures building sustainability according to the project performance for sustainable sites (SS), location and transportation (LT), water efficiency (WE), energy and atmosphere (EA), materials and resources (MR), indoor environmental quality (EQ), the innovation and design process (ID), and regional priority (RP) [1].

1.2.2. WELL Building Standard (WELL)

WELL Building Standard (WELL) is an abbreviation for the WELL Healthy Building Standard, which originated in the United States. The WELL Standard is a performance-based evaluation system that measures, certifies, and monitors characteristics of the built environment—such as air, water, nutrition, light, health, comfort, and spirit—that affect human health and well-being. It was developed by the International WELL Building Institute.

1.2.3. Building Research Establishment Environmental Assessment Method (BREEAM)

The latest version of the Building Research Establishment Environmental Assessment Method (BREEAM) was published in 2014. It consists of nine environmental categories (similar to the categories in LEED), which are: (1) Management, (2) Health and Wellbeing, (3) Energy, (4) Transport, (5) Water, (6) Materials, (7) Waste, (8) Land Use and Ecology, (9) Pollution, and an additional section on (10) Innovation. Various indexes (similar to the credits in LEED) and multiple credits (similar to the points in LEED) are outlined below [2].

1.2.4. Evaluation Standard for Green Building (ESGB)

Since August 1, 2019, the revised Evaluation Standard for Green Building (GB/T50378-2019) has been implemented. In addition to improvements and innovations, the updated index system now includes completely new indicators, forming six categories. Following this revision, the new standard has generally reached an internationally leading level.

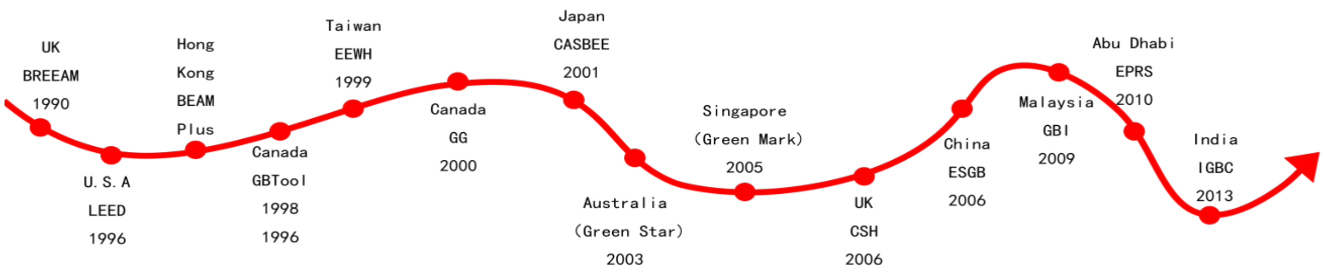

Figure 1. Timetable of mainstream GBRTs established worldwide

1.3. Valuable references

1.3.1. China

This paper provides a horizontal comparison between BREEAM and ESGB, with a particular focus on the similarities and differences in key performance indicators and weighting. Based on the points mentioned above, this paper offers detailed advice for the development of ESGB, contributing to the creation of the best green building assessment methodology suited for China [3].

By comparing the evaluation standard index systems, it is clear that although the evaluation indexes of all countries are based on energy conservation, there is no apparent building carbon emission index. Consequently, the application of a carbon emission index into the green building evaluation system is the main focus of this paper. Secondly, this paper establishes a green building life-cycle carbon emission calculation framework, summarizes the building carbon emission factors, and defines the calculation boundaries and life cycle inventory analysis method. Last but not least, by connecting specific cases, the evaluation standard for an integrated green building evaluation system of carbon emissions will be tested for its efficiency [4]. From Li's standpoint, this study develops an integrated data-driven contrast of the ESGBs of China and the United States. It aims to make clear the current circumstances and further enhance and optimize China's ESGB and popularize green building technologies [5].

1.3.2. International

This research aims to evaluate the difference between projects from versions 3 (v3) and 4 (v4) of the Leadership in Energy and Environmental Design Commercial Interiors (LEED-CI) rating system in China and the US at the Silver and Gold certificate levels [6]. According to Suzer, this study intends to examine the compliance and correlation between the most remarkable green building rating systems, LEED and BREEAM. Given the methodology of the study, the intents of evaluation norms in the latest versions for new constructions of LEED and BREEAM are analyzed and compared [2]. In Park's perspective, regarding the LEED certification as an evaluation system, this study forms an optimization algorithm that intends to originate from the minimum grade for an ideal LEED standard at minimal expense [7].

2. Results and discussion

2.1. Weights

For the green building evaluation systems of various countries, the proportion of indicators, or weights, varies, reflecting the emphasis each system places on promoting the green development of buildings. Weight is a measure that indicates the relative importance of each indicator in the green building evaluation system [3].

2.1.1. Weights in LEED

In LEED-NC2.2 and previous versions, there is no explicit weight system. In the LEED-NC2009 version, the concept of weight was introduced. The weights of the evaluation categories in the latest version of the LEED evaluation system are compared, and their weight ratios are shown in **Figure 2**.

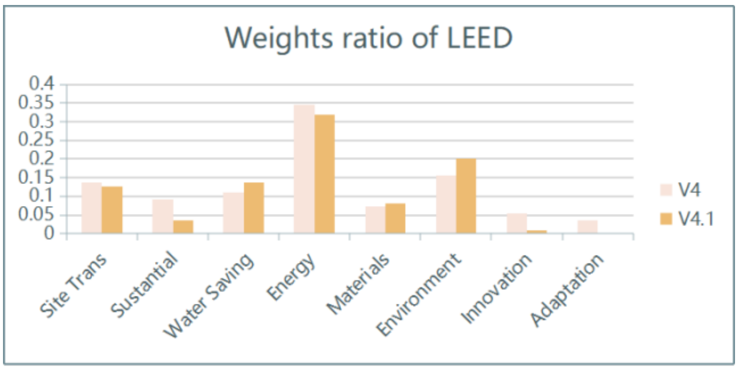

Figure 2. Weights comparison between V4 and V4.1 of LEED

2.1.2. Weights in WELL

The WELL evaluation standard pays more attention to the indoor environment, adding factors such as nutrition, fitness, and mood. The WELL building evaluation standard concerns the health and well-being of people in the constructed environment. In the scoring system, the weight of energy and atmosphere occupies the largest proportion, followed by indoor environmental quality [8]. The specific weight proportion is shown in **Figure 3**.

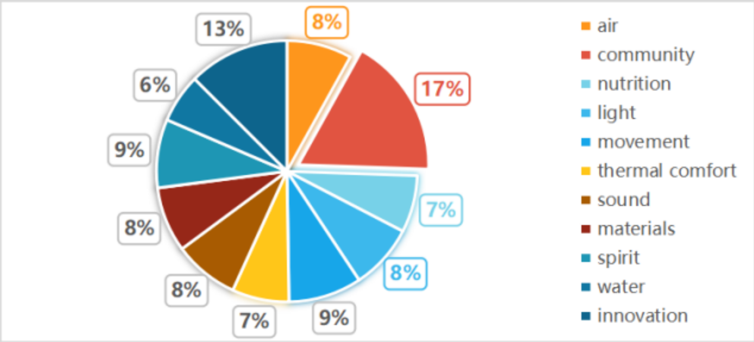

Figure 3. Weight ratio in WELL

2.1.3. Weights in BREEAM

BREEAM and other evaluation systems with a first-level weight system, despite the evaluation method, increase the calculation requirements. BREEAM system has the first-level weight system which is superior to the evaluation system without weight and the evaluation system with multi-level weight. The indicators' weights of BREEAM are shown in **Figure 4**.

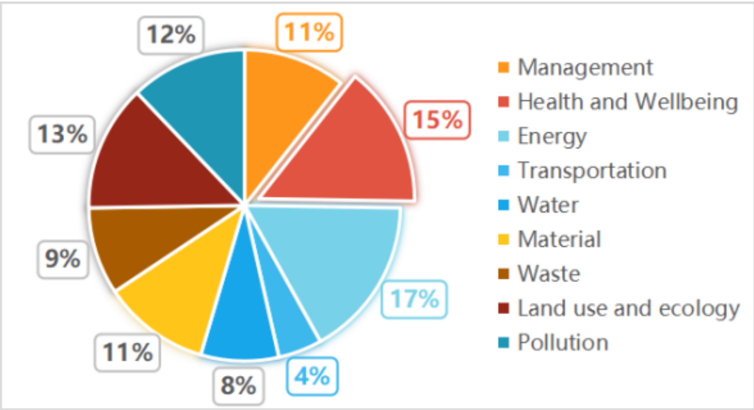

Figure 4. Weight ratio in BREEAM

2.1.4. Weights in ESGB

In the Evaluation Standard for Green Building, China defines green buildings as high-quality buildings that save resources, protect the environment, reduce pollution, provide healthy, applicable, and efficient space for people to use, and maximize the harmonious coexistence between man and nature during the whole life cycle. China's ESGB mainly focuses on the consideration of resource conservation and indoor environmental quality, where specific indicators are shown in **Figure 5**.

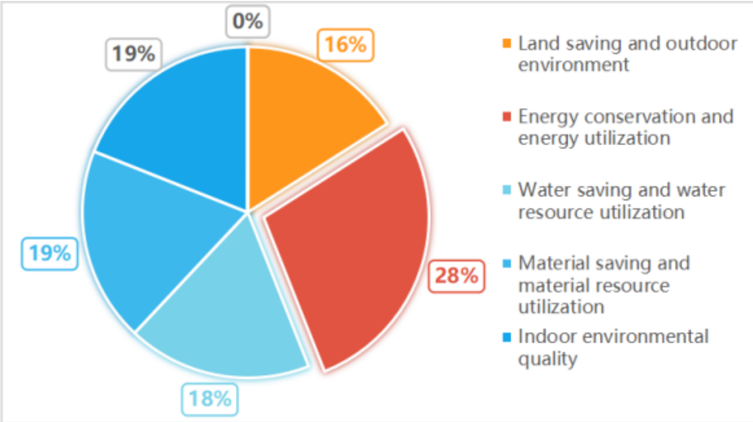

Figure 5. Weight ratio in ESGB

2.2. Evaluation system and calculation methods (ESCM)

With the development and progress of society, there are growing demands for the protection of nature and the improvement of environmental quality. Meanwhile, the construction industry, which is closely linked to human activity, is increasingly drawing attention to its green environmental performance. As early as the 1960s, American architect Paul Soleri introduced the concept of ecological architecture in his book Architectural Ecology: The City in Human Imagination.

2.2.1. ESCM in LEED

The evaluation criteria and weights of LEED v4.0 are as follows: the weight for site selection and transportation is 16%, sustainable site utility accounts for 10%, water efficiency accounts for 11%, energy and atmosphere accounts for 33%, materials and resources account for 13%, and indoor environmental quality accounts for 16%. Integrated design is a prerequisite, and design innovation is awarded as extra credit.

The evaluation method of LEED BD+C uses the cumulative score of each indicator, represented *as* $E = E1 + E2 + E3 + E4 + E5 + E6 + E7 + E8$ (where E is the total building evaluation score and E1–E8 are the scores for each evaluation index) [4]. The specific grade classification is shown in **Table 1**.

Table 1. LEED assessment level

Level	Platinum	Gold	Silver	Certification Level
Score	80+ pts	60–80 pts	49–59 pts	40–49 pts

2.2.2. ESCM in WELL

Certification represents the highest pinnacle of health achievement across all ten concepts. Projects may earn no more than 12 points per concept and no more than 100 points total across the ten concepts. The relevant specific calculation of WELL Certification is shown in **Table 2**.

2.2.3. ESCM in BREEAM

BREEAM sets standards for a broad range of sustainability issues for buildings, communities, and infrastructure in nine categories: energy, waste, water, materials, health and well-being, transportation, pollution, land use and ecology, and stewardship. The specific content is as follows in below **Table 3**.

Table 2. WELL certification of V2.Q1-Q2 2023

Total points achieved	Well certification		Well Core certification	
	Minimum points	Level	Minimum points	Level
40 pts	0	WELL Bronze	0	WELL Core Bronze
50 pts	1	WELL Silver	0	WELL Core Silver
60 pts	2	WELL Gold	0	WELL Core Gold
80 pts	3	WELL Platinum	0	WELL Core Platinum

Sourced from Wellcertified.com

Table 3. BREEAM Evaluation Criteria

Evaluation category	Threshold setting	Score	Weights	Total	Scoring ratio	Certification level
Management	√	23	10.5%		≥ 85%	Outstanding
Health and wellbeing	√	13	12%			
Energy	√	21	16.5%		≥ 70%	Excellent
Transport		9	4.5%			
Water	√	9	7.5%	100%	≥ 55%	Very Good
Material	√	11	11%			
Water	√	6	8.5%		≥ 45%	Good
Land use and ecology		10	17.5%			
Pollution		14	10%		≥ 30%	Pass
Innovation		10	10%	10%		

2.2.4. ESCM in ESGB

The green building evaluation index system consists of seven types of indicators, including land saving and outdoor environment, energy saving and energy utilization, water saving and water resource utilization, material saving and material resource utilization, indoor environmental quality, construction management, and operation management. Operation evaluation should cover seven categories of indicators. The score of the seven indicators Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, and Q_7 is calculated by dividing the actual score value of the score item of the participating building by the total score value of the score item applicable to the building and multiplying by 100 points. The additional score Q_8 for extra points is determined according to the relevant criteria. The total score of green building evaluation is calculated according to the following formula, in which the weights *w1* to *w7* of the seven index scoring items of the evaluation index system are calculated according to the below formulation. The ESGB's specific evaluation criterion is shown in **Table 4**.

$$\Sigma Q = W_1Q_1 + W_2Q_2 + W_3Q_3 + W_4Q_4 + W_5Q_5 + W_6Q_6 + W_7Q_7 + Q_8$$

Table 4. ESGB evaluation criterion

	Land and out-environment, W_1	Energy utilization, W_2	Water utilization, W_3	Materials utilization, W_4	In-environment, W_5	In-management, W_6	Using-management, W_7	Innovation
Design evaluation	0.21	0.24	0.20	0.17	0.18			+0.10
	0.16	0.28	0.18	0.19	0.19			
Operation evaluation	0.17	0.19	0.16	0.14	0.14	0.10	0.10	
	0.13	0.23	0.14	0.15	0.15	0.10	0.10	
Score average	100 pts	100 pts	100 pts	100 pts	100 pts	100 pts	100 pts	10 pts
Score	≥ 50 pts (Each evaluation category evaluates the score item ≥ 40 pts)			≥ 60 pts (Each evaluation category evaluates the score item ≥ 40 pts)			≥ 80 pts (Each evaluation category evaluates the score item ≥ 40 pts)	
Certification level	One-star level			Two-star level			Three-star level	

2.3. Carbon Emissions Calculation (CES)

Currently, the calculation of building carbon emissions has been studied by quite a few people locally and internationally. The calculation of building carbon emissions is mainly the carbon emissions in the operating stage of the building. Most of the research on building carbon emissions in China is based on the whole life cycle of the building. Nevertheless, the current studies are not wholly comprehensive, and there may be omissions in some aspects of calculation, or calculation overlaps in each stage of calculation, which leads to inaccurate calculation [4].

2.3.1. CES and its influential factors

Greenhouse gases are mainly composed of CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCS), Perfluorocarbons (PFCS), and sulfur hexafluoride (SF_6). The main component of which is CO_2. To uniformly measure the environmental impact of other greenhouse gases except CO_2, carbon emissions generated by other greenhouse gases other than CO_2 are converted into carbon dioxide equivalent (Kg CO_2/Kg). Carbon dioxide equivalent refers to the mass of CO_2 that is needed to convert the environmental impact of a certain mass of greenhouse gas into the same environmental impact. Global Warming Potential (GWP) is the value of the unit mass conversion of greenhouse gases other than CO_2 into carbon dioxide equivalent [4].

2.3.2. CES in operating construction phase

In this paper, the carbon emissions generated by the four parts of heating, ventilation, and air conditioning (HVAC), domestic hot water, lighting, elevator, and renewable energy are calculated respectively, and the carbon sequestration amount of the building green space carbon sink system is calculated. Last but not least, the carbon emissions of these five parts are added in total. The calculation formulas of each part are referred to the Building Carbon Emission Calculation Standard [4]. The formula for calculating the carbon emissions of each system in the operation stage of a building is as follows:

$$C_{\mathrm{yx}} = \frac{\sum_{i=1}^{n}(W_i \times \mathrm{q}_i) - Cc\,) \times n}{A}$$

$$W_{\mathrm{i}} = \sum_{j=1}^{n}(W_{i,j} - WR_{i,j})$$

Where C_{yx} is the carbon dioxide emissions generated by the building during its operation phase, i is the type of building energy, j is the system type, q_i is the influence factor of building carbon emission. W_i is the building energy consumption, Cc is the annual carbon emissions fixed by the carbon sink system on the building green space, n represents the service life of the project building, and A represents the construction area of the project.

2.3.3. Building carbon sequestration system

Urban green carbon sink means that green plants absorb carbon dioxide in the air, and fix carbon dioxide in the plant body or soil. At present, local research on carbon sinks mainly focuses on forests, grasslands, and wetlands. The formula for calculating the carbon sink of urban green plants by the green plant type-area method is as follows:

$$C_s = \sum_{i=1}^{n} A_i \times p_i \times \mathrm{n}$$

Where C_s is the carbon sequestration amount of green plants, i is the type of green plants, and p_i is the annual carbon sequestration amount per unit area of a certain kind of green plant.

2.3.4. CES in construction and demolition phases

The carbon emission boundaries of buildings in the construction and demolition stages are defined from two aspects, namely, the time boundary and the space boundary [4]. Building demolition and the carbon emissions of the building demolition stage can be calculated according to the method of the building construction stage. The calculation formulas for the construction and demolition phases are referred to as the Building Carbon Emission Calculation Standard. The carbon emission calculation formula of the building construction stage:

$$MC_{jz} = \sum_{i=1}^{n} CE_{jz,i} \times f_{jz,i}$$

The formula of building demolition stage is as follows:

$$MC_{cc} = \sum_{i=1}^{n} CE_{cc,i} \times f_{cc,i}$$

In the formula, MC represents the carbon emissions in the construction or demolition stage of the building, CE_i is the number of mechanical platforms used in the construction or demolition stage of the building, and f_i is the carbon emission factors of the construction machinery, specifically according to carbon emission factors.

2.3.5. CES in building materials production and transportation stage

Building materials do not produce any greenhouse gases during use, and the source of carbon emissions at this stage is greenhouse gases generated by fossil fuels consumed in the mining, production, transportation, and processing of building materials and raw materials [4]. The carbon emission calculation formula for the building materials production and transportation stage is as follows:

$$C_{JC} = \frac{C_{sc} + C_{ys}}{A}$$

Where C_{sc} is the carbon emission of building materials production stage in the whole life cycle of the building, C_{ys} is the carbon emission generated during the transportation of building materials throughout the building life cycle, C_{jc} is the total carbon emission during this period. Carbon emission formula of building materials production stage is as follows:

$$C_{sc} = \sum_{i=1}^{n} M_i \times F_i$$

Where i is the type of building materials, M_i is the consumption of building materials, and F_i is the carbon emission shadow of building materials sound factor. Carbon emission formula of building materials transportation stage is as follows:

$$C_{ys} = \sum_{i=1}^{n} M_i \times D_i \times T_i$$

Where D_i is the transportation distance of building materials from the production site to the construction site and T_i is the influence factor of carbon emission during the transportation of building materials.

3. Conclusion

3.1. Optimization of weights in ESGB

According to the weight comparison of the green construction evaluation system locally and internationally, the following conclusions can be drawn to improve and enhance China's ESGB green construction evaluation system:

(1) The weight ratio should be adapted to local conditions and people-oriented.

(2) The weight ratio needs to set thresholds of different heights according to the score level.

(3) The weight ratio needs to be more quantitative, set multi-level weights, and set weights flexibly according to changes in objective conditions.

(4) According to the weight and scoring criteria of the green construction evaluation system.

(5) The ESGB evaluation system is recommended to include the design stage, construction stage, operation stage, demolition stage, and many more.

3.2. Optimization of ESCM in ESGB

This paper summarizes the scoring standards and certification levels of different green construction evaluation systems, both locally and internationally, and analyzes their respective advantages and disadvantages. The following recommendations are proposed:

(1) Establish an efficient certification and evaluation process by integrating expert certification into the design and construction drawings of the building scheme. Conduct regular reviews every two years at all stages of the building life cycle, collect data for feedback during the completion and operation stages, and establish a green building expert evaluation responsibility system.

(2) From the perspective of evaluation indicators, China's ESGB lacks consideration of human health, detailed indoor quality evaluation standards, and harmony with the outdoor natural environment. More of these considerations should be incorporated into the evaluation indicators.

3.3. Optimization of CES in ESGB

There are many ways to divide the entire life cycle of buildings, and the calculation of building carbon emissions overlaps with those of the building materials industry and transportation. Furthermore, most carbon emission calculation systems are not perfect. Therefore, this paper divides the life cycle of buildings into three stages: the building operation stage, the building construction and demolition stage, and the building production and transportation stage. Carbon emissions are calculated according to different emission factors in each stage. Most importantly, we are committed to achieving the target of carbon peak and carbon neutrality on schedule.

Disclosure statement

The author declares no conflict of interest.

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