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A Comparative Study of the Latest Editions of China–Japan–US Green Building Evaluation Standards

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Abstract: The Green Building Evaluation Standard (ESGB) has become an important support for China's building sector in realizing the "double carbon" goal. However, there remains a lack of comprehensive research on the historical evolution and development status of the ESGB. This study firstly analyzes the updating logic and development strategy of the three versions of the ESGB, then compares the differences between ESGB 2019, CASBEE-NC 2014, and LEED O+M v4.1 from the perspective of the index system, and further examines the current international application status of the ESGB. The results show that LEED focuses on decarbonization and ecological protection, while CASEBB focuses on the concept of humanization and positively influences the local real estate market, and ESGB 2019 contains more health and comfort considerations than its previous version and is close to the internationally advanced level in terms of provision setting and international application. This study offers valuable insights into the potential for further refinement of green building standards in China and highlights areas for future research, including enhancing the ESGB's adaptability and integration with emerging technologies to promote global sustainable development.

Keywords: green building evaluation standard; index system; comparative study; application analysis; sustainability development

Citation: Wang, Q.; Gao, W.; Su, Y.; Zhang, Y. A Comparative Study of the Latest Editions of China–Japan–US Green Building Evaluation Standards. *Buildings* **2024**, *14*, 3698. https://doi.org/10.3390/buildings14113698

Academic Editor: Giuseppina Uva

Received: 14 October 2024
Revised: 9 November 2024
Accepted: 19 November 2024
Published: 20 November 2024

1. Introduction

Since the 1970s, the energy crisis and global warming have become major problems for countries worldwide. Controlling energy consumption in buildings is important for realizing energy security and combating climate change. In the sustainable development of the construction industry [1], green buildings not only provide better living and working environments for users but also effectively utilize energy, water, and other resources [2,3]. They are considered a crucial strategy in addressing climate change. Following the release of the Building Research Establishment Environmental Assessment Method (BREEAM), the first green building assessment standard in the UK [4], Leadership in Energy and Environmental Design (LEED) has become the most widely used rating system globally, developed by the U.S. Green Building Council (USGBC) in 1998 [5]. Countries worldwide have established green building evaluation standards and certifications tailored to their specific needs, considering various building types and their entire life cycles [6,7]. For instance, the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), jointly developed by academia, industry, and local governments in Japan, offers one of the most comprehensive assessment scopes [8–10]. Green building assessment standards have been shown to improve building energy efficiency, improve the operational benefits of green buildings, increase user comfort and satisfaction, and promote related industry innovation and socio-economic development [11,12]. Therefore, the widespread promotion and application of well-developed green building assessment standards are essential in addressing these environmental challenges. As China's urbanization and modernization processes accelerate, the country's building energy consumption and carbon dioxide emissions have increased significantly since the second half of the 20th century [13], even surpassing those of developed countries. The need to implement building energy-saving policies in China has become increasingly pressing [14]. In response, the Chinese Ministry of Housing and Urban-Rural Development (MOHURD) has released ESGB 2006, followed by the latest version, ESGB 2019. The revised ESGB has restructured its indicator system, emphasizing whole-life carbon emissions more, to support China's goal of achieving "dual carbon" targets [15]. The "dual carbon" goal refers to China's commitment to reaching peak carbon emissions by 2030 and achieving carbon neutrality by 2060. The focus on reducing whole-life carbon emissions in the ESGB aligns with this national strategy by promoting sustainable building practices that contribute to lower carbon footprints throughout a building's lifecycle. Therefore, it is essential to conduct an in-depth examination of the ESGB, continually improving its practical application quality, to promote the effective development of green buildings in China and help achieve these ambitious carbon targets [16,17]. Further refinement of the ESGB will support the development of green buildings in China, contributing to a more sustainable built environment.

The evaluation system and application research of green building assessment standards represent an important direction in the field of green building. This study focuses on three well-known systems: LEED from the United States, CASBEE from Japan, and the ESGB from China, deeply analyzing their evolution and development strategies. These standards were chosen for their global influence, comprehensiveness, and relevance to the challenges faced by China's construction industry. LEED is recognized for its strong focus on energy efficiency and carbon emission control, CASBEE emphasizes lifecycle impacts and the integration of urban density, while the ESGB aligns with China's local climate conditions, socio-economic needs, and sustainable development policies. By comparing these three systems, this study aims to address existing research gaps, as most current studies either focus on broad comparisons among global standards or the evolution of a single standard. This paper combines both approaches. This dual approach, combining ESGB's development with a comparison to established international standards, aims to highlight ESGB's strengths and areas where successful practices from other systems could be adapted. Ultimately, this research provides valuable references for promoting sustainable building practices in China and beyond.

2. Literature Review

Studies indicate that comparative research on green building evaluation standards across different countries can effectively enhance the level of local green building practices. For instance, one study compared the credit structures and indicators of ten widely used green building rating systems in North America, Europe, and Asia, offering recommendations to improve India's green building rating system [18]. Another study examined BREEAM, LEED, CASBEE, and Green Globes, exploring how these systems might be applied to the existing building conditions in Kazakhstan [19]. Additionally, a comparative study on nine green building evaluation standards from developed and developing countries found that while most systems primarily focus on environmental and economic aspects, attention to social dimensions remains relatively limited [20]. Another study comparing the lighting standards of LEED and BREEAM proposed new recommendations for green building practices in Serbia [21]. Furthermore, a study that compared LEED with three other green building rating systems introduced a method to improve local green building performance through energy credits [22]. Green certification systems have significantly driven the development of green buildings, emphasizing the need for more comprehensive evaluation criteria to identify key areas for improvement.

By comparing green building standards across various countries, researchers have gained diverse insights. For example, comparisons of green building standards in China, the UK, and the US indicate that both China and the US effectively address the technical pathways necessary for achieving sustainable green building development [23]. Lee's comprehensive review of LEED, BREEAM, and CASBEE identified that while LEED excels in multiple environmental performance metrics, it has limitations in resource management and social impact evaluation, which can hinder its applicability in some emerging economies [24]. LEED's strength lies in its broad focus on environmental performance, particularly in energy efficiency and carbon emission control [25]. CASBEE, as Japan's primary green building evaluation system, emphasizes balancing environmental benefits with urban density, making it especially suitable for densely populated urban areas. However, its complexity and limited attention to social impacts pose challenges for broader international adoption [24].

Additionally, Gao et al. compared the US-based LEED with China's ESGB across five aspects: energy efficiency, site selection, water conservation, material efficiency, and indoor environment, highlighting the ESGB's adaptability to local climatic and construction practices while pointing out areas for improvement in social and economic considerations [26]. Nong et al. analyzed changes in water supply and drainage provisions in the new and previous versions of the ESGB, illustrating progress in technical specifications [27]. Ma et al. compared two ESGB versions, examining the evolution in classification and evaluation standards, which reflects enhancements in adaptability and technical aspects [28]. Furthermore, a cross-sectional comparison of the ESGB with Taiwan's EEWH focused on differences in evaluation stages and indicator settings [29]. Another study conducted a multi-dimensional comparison of green building standards in China and the US, summarizing each system's weighting characteristics, advantages, and disadvantages [30,31]. Through comparative studies of green building evaluation systems in other countries, valuable insights can be gained to guide the formulation and improvement of national green building standards.

In addition to examining these differences, researchers have noted that the demand for energy conservation has risen in response to low-carbon policies [32]. Wang et al. developed a topology optimization approach for multi-material active structures aimed at reducing energy consumption and greenhouse gas emissions, highlighting the potential for green building systems to incorporate advanced structural designs for enhanced sustainability [33]. Li et al. proposed a multi-dimensional optimization approach for net-zero energy buildings, focusing on balancing energy efficiency, transportation efficiency, and economic durability to achieve sustainable development goals [34]. A comparative study of Singapore's Green Mark and China's ESGB in their old and new versions highlighted substantial improvements in ESGB's evaluation objects, scoring criteria, and category settings to meet energy-saving and low-carbon requirements [35]. Additionally, comparisons between green building standards in China–Singapore and China–US led to suggestions for enhancing ESGB's evaluation content, grade classifications, and policy incentives [36,37]. An analysis comparing the ESGB with the UK's BREEAM emphasized the need to strengthen control over the implementation effects of green building standards [38]. Therefore, driven by low-carbon policies and changes in the international environment, green building evaluation systems require continuous updates and improvements to adapt to global development needs.

While current ESGB research mainly focuses on technical analysis, discussions on its development status and trends in international applications are becoming increasingly important. Therefore, this study selects three versions of China's ESGB for an in-depth and systematic evolutionary analysis, exploring differences and connections among green building evaluation standards in China, Japan, and the US. This paper aims to provide a better understanding of the priorities and approaches in green building evaluation across different countries, highlighting the strengths and limitations of each standard. By analyzing these comparisons, we seek to achieve a balance between the international applicability and localization of the ESGB. Ultimately, this study provides a new perspective on the dynamics of green building development in China and serves as a reference for the improvement of green building evaluation standards worldwide.

3. Research Method

This study first conducts a vertical analysis of three key versions of the ESGB, which mark significant developments in China's green building evaluation system, aiming to reveal the underlying patterns and characteristics in the updates of the ESGB. Subsequently, the study compares the ESGB, LEED, and CASBEE green building evaluation standards, with a focus on analyzing their evaluation indicators, methods, and revision details, especially in key areas such as energy efficiency, water resource management, and material sustainability.

In terms of data collection, this study analyzes the official documents and the most recent versions of each standard, while also referencing relevant literature to ensure a comprehensive understanding of each standard. For in-depth comparison, the research framework covers multiple key evaluation dimensions, including environmental impact, technological flexibility, and alignment with global sustainable development goals. Finally, it discusses the international development of the ESGB and how it draws insights from international standards.

4. Vertical Comparison of China's Green Building Evaluation Standard

4.1. The Development Background of China's Green Building Evaluation Standard

In 1986, China's first building energy efficiency standard was promulgated, marking the beginning of China's building energy efficiency development. In 2008, the Chinese government formally incorporated building energy efficiency into the national economic and social development plan, making it an essential component of the country's ecological civilization construction and sustainable development strategy. In 2006, MOHURD issued the first green building evaluation standard, ESGB 2006. In March 2019, MOHURD released ESGB 2019, and in May 2020, the English version of ESGB 2019 was officially approved for use. The new green building standard has reconstructed a green building evaluation indicator system with Chinese characteristics, oriented towards performance and incorporating people-centered thinking [39].

LEED entered the Chinese market in 2001 and has gradually become one of China's primary green certification systems. China has the largest number of LEED-certified projects, with a total of 3620 projects certified as of the end of 2023 [40]. Notably, the number of projects evaluated by ESGB had already reached 4515 by September 2016 [41], surpassing the number of LEED-certified projects. After multiple updates and refinements, the ESGB standard has become more widely applied in China. Therefore, analyzing the updates to the ESGB version and changes to its evaluation indicators and summarizing the progress and impact of this evaluation standard are crucial for the future development of green buildings in China.

4.2. Vertical Comparison Between ESGB 2006, ESGB 2014, and ESGB 2019

ESGB 2006 categorized evaluation indicators by building type, dividing them into public and residential buildings, and further classified them into control items, general items, and preferred items. Figure 1 shows the proportions of retained, modified, and newly added clauses in ESGB 2014 compared to the previous version. The updated ESGB 2014 achieved significant improvements in three aspects: building controllable scope, technical diversity, and quantifiable indicators.

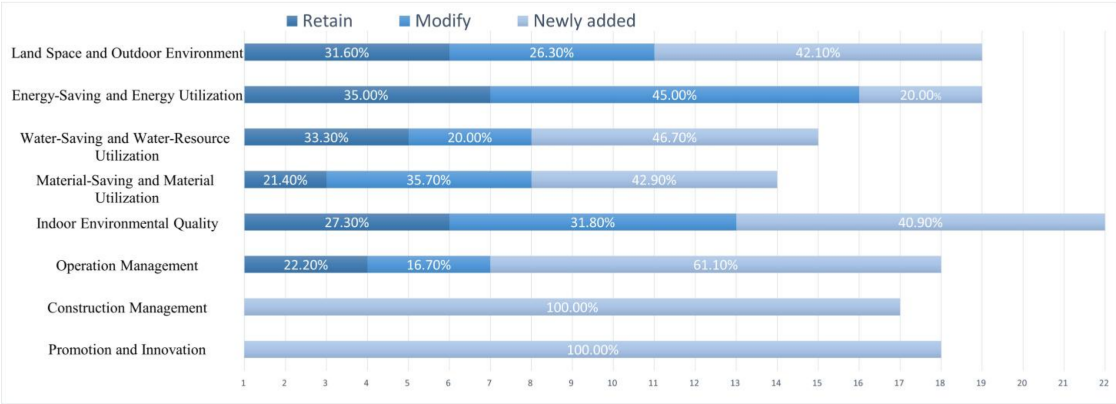

Figure 1. Indicator changes in ESGB 2014.

The addition and modification of operation management evaluation indicators had the largest scope, reaching 77.8%. This part emphasized the normal operation and regular inspection and optimization of facilities, equipment, and automated monitoring systems, proposing intelligent and eco-friendly management methods. The modification and addition of indoor environmental quality evaluation indicators was 72.7%, mainly adding specific acoustic design requirements. Additionally, new requirements were proposed for shading facilities and heating, ventilation, and air conditioning systems. The "Construction Management" and "Promotion and Innovation" evaluation indicators, first introduced in ESGB 2014, focused on the potential for low-carbon building improvements and the adoption of innovative energy-saving technologies and respectively.

ESGB 2019 has reorganized the evaluation indicator system, modifying the previous indicators into five aspects: "Safety and Durability", "Health and Comfort", "Occupant Convenient", "Resource Saving", and "Environment Livable". The system integrates a "people-centered" development philosophy. Additionally, the evaluation grades have been increased from three to four, with a new "Basic Level" introduced. The new version emphasizes that all participating buildings should undergo full decoration, preventing the modification or cancellation of green building technologies during the construction process, to ensure the integrity and operational performance of green buildings.

Figure 2 shows the proportions of retained, modified, and newly added clauses in ESGB 2019 compared to the previous version. The most significant change occurred in the "Safety and Durability" indicator, with a modification and addition rate of 88.2%. This indicator incorporates some of the "Land Use" and "Energy Efficiency" indicators from the 2014 version, emphasizing the durability, moisture resistance, fire protection, and maintainability of building envelopes, main structures, non-structural components, and interior finishes. The measures covered by this indicator, such as ensuring unobstructed evacuation routes, using products and components with safety protection functions, and installing anti-slip facilities, reflect the importance placed on personnel safety.

The "Occupant Convenient" indicator was modified and expanded by 73.7%. This indicator integrates the "Land Use and Outdoor Environment" from the previous version, adding user-friendly services and facilities, and optimizing the content of operation and management. It specifies the requirements for buildings to address social aging and emphasizes barrier-free design in indoor and outdoor public areas. Additionally, the design of outdoor public spaces should meet the cultural and fitness needs of users. In terms of intelligent operation, the new version includes the setup of remote metering systems and remote monitoring systems to optimize the intelligent management of buildings and reduce the waste of human resources.

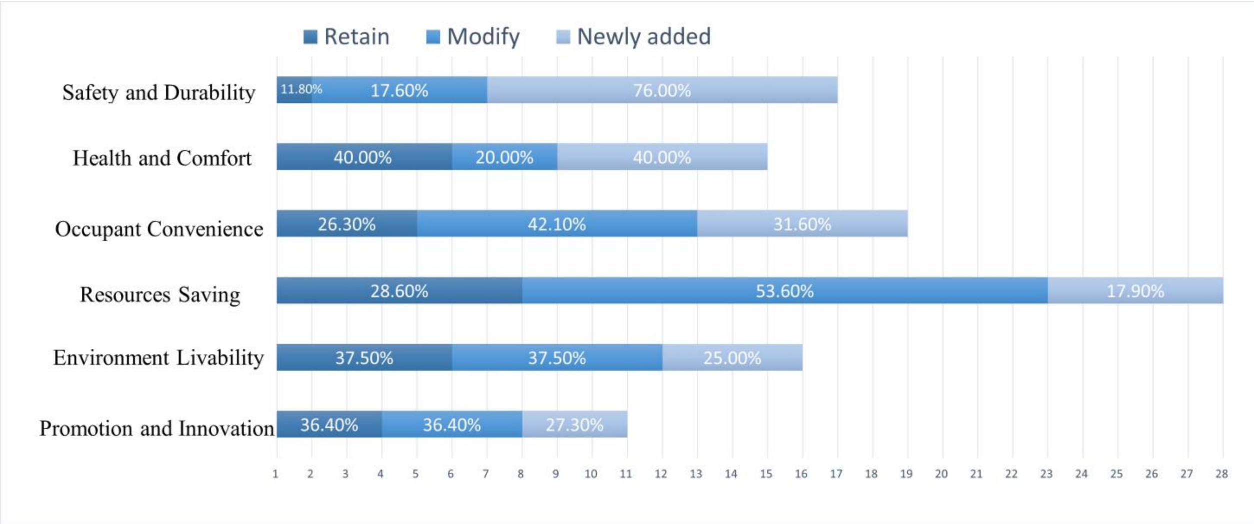

Figure 2. Indicator changes in ESGB 2019.

Table 1 compares the three versions of China's green building standards. Overall, ESGB 2019 has streamlined and simplified the indicator system and quantity, making it easier to understand and implement. Regarding certification modes, ESGB 2019 is more aligned with international mainstream standards. For example, the newly added "Basic Level" in ESGB 2019 is similar to the "PASS" certification level in LEED. The new ESGB considers the uneven development of different regions in China and facilitates the promotion of green buildings and international exchanges.

Table 1. ESGB standard vertical comparison.

		ESGB 2006	ESGB 2014			ESGB 2019
Land Saving and Outdoor Environment	N	14	19	**Environment Livable**	N	16
	W	None	0.13		W	0.16
	CI	Site Selection (3)	Site Selection (3)		CI	Reasonable Building Planning and Layout (1)
		Reasonable Building Planning and Layout (1)	Reasonable Building Planning and Layout (1)			Outdoor Physical Environment (1)
		Environmental Protection During Construction (1)	None			Site Ecology and Landscape (3)
	GI and SI	Land Use (2)	Land Use (3)			Site Design (2)
		Outdoor Physical Environment (2)	Outdoor Physical Environment (4)		SI	Site Ecology and Landscape (5)
		Mobility and Accessibility (1)	Traffic Facilities (3)			
			Public Service (1)			
		Site Design and Ecology (1)	Site Design and Ecology (4)			Outdoor Physical Environment (4)
	OI	Intensive Use of Land (1)	None			
		Use of Old Buildings (1)				
		Permeable Ground (1)				

Table 1. *Cont.*

		ESGB 2006	ESGB 2014
Energy Conservation and Energy Utilization	N	19	20
	W	None	0.23
	CI	Building Envelope (1)	Energy-Saving Design (1)
		Heating and Air Conditioning (2)	Heating and Air Conditioning (1)
		Illumination (1)	Illumination (1)
		Energy Consumption Measurement (1)	Energy Consumption Measurement (1)
	GI and SI	Building Envelope (3)	Building Envelope (3)
		Heating, Ventilation, and Air Conditioning (2)	Heating, Ventilation, and Air Conditioning (5)
		Lighting and Electrical (1)	Lighting and Electrical (4)
		Utilization of Energy (3)	Utilization of Energy (4)
		Energy Consumption Measurement (1)	None
	OI	Utilization of Energy (3)	None
		Illumination (1)	
Water Saving and Water Resource Utilization	N	12	15
	W	None	0.14
	CI	Utilization of Water (1)	Utilization of Water (1)
		Water-Saving System (2)	Water-Saving System (1)
		Water-Saving Appliance (1)	Water-Saving Appliance (1)
		Unconventional Water Use (1)	None
	GI and SI	Water-Saving System (1)	Water-Saving System (5)
		Water-Saving Appliance (1)	Water-Saving Appliance (4)
		Unconventional Water Use (4)	Unconventional Water Use (3)
	OI	Unconventional Water Use (1)	None
Material-saving and Material Resource Utilization	N	12	17
	W	None	0.15
	CI	Material-Saving Design (1)	Material-Saving Design (1)
		Material Selection (1)	Material Selection (2)
	GI and SI	Material-Saving Design (2)	Material-Saving Design (6)
		Material Selection (6)	Material Selection (8)
	SI	Material-Saving Design (1)	None
		Material Selection (1)	

ESGB 2019			
Resource Saving	N	28	
	W	0.33	
	CI	**Land Saving**	Building Envelope (1)
		Energy Saving	Heating, Ventilation, and Air Conditioning (2)
			Lighting and Electrical (2)
			Energy Consumption Measurement (1)
		Water Saving	Utilization of Water (1)
		Material Saving	Material Saving Design (2)
			Material Selection (1)
	SI	**Land Saving**	Land Use (2)
			Traffic Facilities (1)
			Building Envelope (1)
		Energy Saving	Heating, Ventilation, and Air Conditioning (2)
			Lighting and Electrical (1)
			Energy Utilization (2)
		Water Saving	Water-saving Appliance (2)
			Unconventional Water Use (2)
		Material Saving	Material-Saving Design (1)
			Material Selection (4)

Table 1. *Cont.*

		ESGB 2006	ESGB 2014		ESGB 2019	
Indoor Environmental Quality	N	15	20	**Health and Comfort**	N	20
	W	None	0.15		W	0.17
	CI	Acoustic Environment (1)	Acoustic Environment (2)		CI	Acoustic Environment (1)
		Light Environment (1)	Light Environment (1)			Light Environment and View (1)
		Heat and Humidity Environment (3)	Heat and Humidity Environment (3)			Heat and Humidity Environment (3)
		Air Quality (1)	Air Quality (1)			Air Quality (2)
	GI and SI	Acoustic Environment (2)	Acoustic Environment (4)			Pollutant Control (1)
		Light Environment and View (1)	Light Environment and View (3)			Water-Saving System (1)
		Heat and Humidity Environment (1)	Heat and Humidity Environment (2)		SI	Acoustic Environment (2)
		Air Quality (1)	Air Quality (4)			Light Environment and View (1)
		Convenient Facilities (1)	None			Heat and Humidity Environment (3)
	OI	Light Environment and View (1)	None			Air Quality (2)
		Heat and Humidity Environment (1)				Water Quality (3)
		Air Quality (1)				
Operation Management	N	11	18	**Safety and Durability**	N	17
	W	None	0.10		W	0.17
	CI	Management System (1)	Management System (2)		CI	Project Location (1)
		Environmental Management (2)	Environmental Management (1)			Architecture and Structure (5)
		None	Technical Management (2)			Reasonable and Smooth Passage (1)
	GI and SI	Management System (2)	Management System (4)			Safety Management (1)
		Technical Management (4)	Technical Management (5)		SI	Building Safety (1)
		Construction and Operation (1)	Environmental Management (4)			Personnel Safety (1)
	OI	Management System (1)	None			Safety Design and Facilities (3)
						Durability (4)
Construction Management	N	None	17	**Occupant Convenient**	N	19
	W		0.1		W	0.17
	CI		Environmental Protection (1)		CI	Mobility and Accessibility (4)
			Process Management (2)			Technical Management (2)
			Personnel Management (1)		SI	Mobility and Accessibility (2)
	GI and SI		Environmental Protection (3)			Service Facility (3)
			Resource Saving (5)			Intelligent Operations (4)
			Process Management (5)			Property Management (4)

Table 1. *Cont.*

		ESGB 2006	ESGB 2014			ESGB 2019
Promotion and Innovation	N	None	12	**Promotion and Innovation**	N	10
	W		/		W	None
	AI		Land-Saving and Outdoor Environment (1)		AI	Land-Saving and Outdoor Environment (2)
			Energy Conservation and Energy Utilization (3)			Energy Conservation and Energy Utilization (1)
			Water-Saving and Water Resource Utilization (1)			None
			Material-Saving and Material Resource Utilization (1)			Material-Saving and Material Resource Utilization (1)
			Indoor Environmental Quality (2)			Construction and Management (2)
			Innovate (4)			Innovate (4)

5. Comparative Analysis of Key Evaluation Indicators for Green Building Standards: Insights from China, Japan, and the United States

This chapter compares and analyzes the evaluation indicators of LEED O+M v4.1, CASBEE-NC 2014, and ESGB 2019 across five aspects: outdoor environment, water conservation and utilization, energy conservation and utilization, material conservation and utilization, and indoor environment.

For the outdoor environment, LEED O+M v4.1 includes specific parameters for ecological management, allowing for a quantitative assessment of environmental impact. It also evaluates "Transportation Performance", which examines users' transportation choices to promote low-carbon travel and enhance outdoor quality. CASBEE-NC 2014 focuses more on outdoor comfort, with requirements to mitigate thermal conditions in summer. Measures include breezeways, shaded areas, green and water spaces, and the use of appropriate exterior materials for thermal control. CASBEE-NC 2014 also uniquely provides real-world case studies for user reference. ESGB 2019 offers detailed sub-categories for outdoor environment evaluation, mainly emphasizing site ecology and landscape, though it has fewer comfort-related indicators compared to CASBEE-NC 2014.

In water conservation and utilization, LEED O+M v4.1's water management relies on high-performance building consumption data, with strict requirements for irrigation, sanitary appliance efficiency, and cooling tower evaporation rates. CASBEE-NC 2014 encourages the use of water-saving appliances, reducing both consumption and discharge, and promotes rainwater and gray water reuse. ESGB 2019 provides the most comprehensive water conservation indicators, covering aspects such as rainwater harvesting, irrigation usage, water-saving equipment, and the use of alternative water sources to maximize conservation.

For energy conservation, LEED O+M v4.1 monitors total building energy use and greenhouse gas emissions through its "Energy Management" indicator, using data from both high- and low-performance buildings to support green evaluation. CASBEE-NC 2014 incorporates Japanese regulations, emphasizing carbon emissions reduction and improved energy efficiency through optimized layouts and energy-saving measures. ESGB 2019 focuses on enhancing energy efficiency by optimizing building envelopes and key systems like HVAC.

In material conservation and utilization, LEED O+M v4.1 prioritizes waste management to minimize environmental impact during building operation, maintenance, and renovation. CASBEE-NC 2014 stresses strict site management and responsible material procurement, with requirements for documentation and inspections to reduce construction waste. ESGB 2019 emphasizes sustainable and reusable materials, encourages durable structures to minimize repair costs, and seeks to reduce waste from on-site operations.

For the indoor environment, LEED O+M v4.1 emphasizes air quality and user comfort, requiring pollutant measurements and user surveys to optimize indoor air quality. CASBEE-NC 2014 mandates dedicated rest and amenity areas to enhance comfort, requiring such spaces to occupy at least 2% of the total building area. ESGB 2019 aims to improve indoor conditions in acoustics, lighting, and thermal comfort but lacks post-occupancy evaluation and detailed air quality requirements.

In summary, LEED O+M v4.1 excels in ecological management, energy monitoring, waste management, and indoor air quality, with a strong focus on user feedback. CASBEE-NC 2014 emphasizes user comfort, safety, carbon reduction, and efficient material use through rigorous site management. ESGB 2019 offers the most comprehensive framework for water and material conservation and emphasizes energy efficiency. Synthesizing these findings highlights potential improvements for ESGB, such as adopting LEED's indoor air quality measures and CASBEE's focus on comfort and site-specific adjustments, to strengthen its applicability on a global scale.

6. Synthesis and Evaluation of Green Building Systems in China, Japan, and the United States

6.1. Policy Impact

Reducing energy consumption is a crucial aspect of building performance, and the advancement of energy-saving and emission-reduction technologies is heavily dependent on comprehensive supportive policies at both regional and local levels [42]. This section examines the impact of policies on green building initiatives in the United States, Japan, and China, focusing on national-level directives, mandatory measures, and financial incentives that promote compliance.

In the United States, significant legislation, such as New York State's "Climate Leadership and Community Protection Act" of 2019, mandates an 85% reduction in greenhouse gas emissions across all sectors, including transportation and construction, by 2050. Furthermore, states like New Jersey require new buildings to achieve at least LEED Silver certification, supported by tax credits and other incentives that facilitate LEED adoption nationwide. Notably, around 74% of Americans now live in states with energy efficiency regulations for buildings, reflecting strong policy backing for green building practices [43].

Japan has also made strides in green building policies through CASBEE, aligning its goals with the national objective of achieving carbon neutrality by 2050. As of September 2022, 24 local governments in Japan have made CASBEE a mandatory standard, requiring the submission and publication of CASBEE assessment results on local government websites for new or expanded buildings exceeding a certain size. Simultaneously, local governments offer incentives such as lower mortgage interest rates and floor area ratio bonuses for buildings with higher CASBEE assessment ratings, promoting sustainable development that aligns with national environmental objectives [44].

In China, the ESGB standard signifies the nation's commitment to harmonizing domestic green building standards with international benchmarks while pursuing its "dual carbon" goals—achieving peak carbon emissions by 2030 and carbon neutrality by 2060. The Ministry of Housing and Urban–Rural Development aims for all new buildings to meet green standards by 2025, demonstrating a comprehensive policy alignment with broader national sustainability priorities [45]. Each of these systems not only includes mandatory requirements but also encourages public awareness and engagement in the shift toward greener building practices.

6.2. Evaluation Content

Green building evaluation systems have significantly evolved to meet market demands and local needs [3]. This section analyzes LEED, CASBEE, and the ESGB based on three key parameters: environmental impact, adaptability, and responsiveness to policy evolution, offering a comparative framework to highlight each system's unique approach.

All three systems prioritize minimizing environmental impact, although their focuses differ. LEED emphasizes energy efficiency, ecological management, and waste re-duction across a building's lifecycle, implementing rigorous monitoring of energy use and greenhouse gas emissions. Moreover, LEED has shown flexibility in adopting emerging technologies by continuously updating its standards to include advanced energy-efficient systems, such as smart energy management tools, solar panels, and building-integrated photovoltaics (BIPVs), ensuring it remains adaptable to the latest green technologies. In the case of water conservation, LEED encourages the adoption of cutting-edge water-saving technologies, such as rainwater harvesting systems and water-efficient irrigation systems, to enhance sustainability across building operations.

In contrast, CASBEE addresses specific local environmental factors, such as mitigating urban heat island effects and integrating green and water spaces, making it well suited to Japan's unique urban and climatic challenges. And CASBEE supports the integration of advanced energy-efficient solutions like heat recovery ventilation systems and high-efficiency HVAC systems. The ESGB, aligned with China's sustainable development objectives, focuses on conserving water and materials, linking its strategies directly to China's dual carbon goals and advocating for sustainable resource use throughout the building lifecycle. This includes flexibility in adopting new water-saving technologies, such as greywater recycling systems, and advanced materials like phase-change materials (PCMs) to improve thermal comfort and reduce energy use.

Adaptability is a crucial factor in how well each system can respond to changing market needs and regulatory contexts. LEED is known for its frequent updates, guided by stakeholder feedback and evolving industry standards, ensuring that it remains relevant globally and adapts to different building types and regional conditions. In April 2024, the USGBC released the first public comment draft of LEED v5, with an official version expected in the first quarter of 2025 [46]. CASBEE's adaptability is driven by its detailed manuals for local governments, and in May 2024, it released the "CASBEE-Architecture Evaluation Manual 2021 SDGs Compatible Supplement Version 2.3", aimed at enhancing sustainability principles [47]. This allows local adaptations while maintaining compliance with Japanese regulations, such as the "Energy Conservation Law".

The ESGB primarily targets residential and public buildings, emphasizing flexibility in evaluating regional differences by selecting relevant criteria for assessment during both design and operational phases. The recent version of the ESGB has transitioned from the original item-counting method to the internationally common point-counting method. Its five categories of indicators include both scoring and bonus items, with control items and scoring items for each category. Buildings that meet all control items are rated at the "Basic Level", equivalent to the "PASS" level in LEED, enhancing the ESGB's international applicability. This systematic update approach allows the ESGB to continuously adapt to global environmental changes, thereby better supporting the development of green buildings in China and strengthening its competitiveness in international markets.

Responsiveness to policy evolution further distinguishes each system's ability to align with changing regulatory requirements. LEED benefits from a flexible update approach, informed by stakeholder feedback and industry standards, allowing it to remain adaptable to diverse regional needs. CASBEE, on the other hand, is integrated into Japanese municipal policies as a mandatory standard, with strong financial incentives that encourage high performance in buildings and urban areas. While the ESGB is closely aligned with China's sustainability goals and remains consistent with policy changes, it could further benefit from adopting LEED's market-driven adaptability and CASBEE's mandatory integration and incentive mechanisms to enhance its applicability and competitiveness on a global scale.

Table 2 summarizes the key attributes of LEED, CASBEE, and the ESGB. In summary, LEED is distinguished by its flexibility and regular updates, allowing it to address a variety of regional needs while emphasizing energy management and environmental integration. CASBEE covers a broad evaluation scope, including buildings, housing, and urban areas, with adaptations primarily driven by regulatory changes. The ESGB is specifically tailored to China's requirements, focusing on public and residential buildings, enhancing both its national relevance and international competitiveness. This comparative analysis highlights the strengths of each system and provides specific directions for enhancing the effectiveness of ESGB in global green building practice.

Table 2. Overview of Chinese, Japanese and American green building standards.

	ESGB 2006	ESGB 2014	ESGB 2019	LEED v3.0	LEED v4.0	LEED v4.1	CASBEE
Range	Residential Buildings; Shopping Malls; and Hotel Buildings	Green Buildings	Green Buildings	New Construction; Core and Shell; Healthcare; Schools; Retail; Existing Buildings; Commercial Interiors; Residential; Communities	BD+C: Building Design and Construction		Certification for Buildings
					O+M: Operations + Maintenance for Existing Public Buildings	O+M: Operations + Maintenance for Architecture and Interior Design	Certification for Housing
					Interior Design + Construction Guide	Residential	Certification for Urban
					Neighborhood Development Guide	Cities and Communities	Certification for City
					Homes		
Evaluation Phase	Design Stage; Operation Stage; Building Life Cycle	Design Stage; Operation Stage; Building Life Cycle	Design Stage; Operation Stage; Building Life Cycle Pre-evaluation	Building Life Cycle; Design Evaluation and Construction Evaluation			Design Stage, Operation Stage, Building Life Cycle;
Rank	Item Counting Method	One Star 50–59 Two Star 60–79 Three Star ≥ 80	Basic Level One Star 60–69 Two Star 70–84 Three Star ≥ 85	Pass 40–49 Silver 50–59 Gold 60–79 Platinum 80–110	Pass 40–49 Silver 50–59 Gold 60–79 Platinum 80–110	Pass 40–49 Silver 50–59 Gold 60–79 Platinum 80–100	S(Excellent)BEE ≥ 3.0, Q ≥ 50 A (Very Good) BEE ≥ 1.5~3.0 or BEE ≥ 3.0, Q < 50 B+(Good) BEE = 1.0~1.5 B-(Fairy Poor)

7. Discussion

As green buildings in China have developed steadily, the awareness, understanding, and demand for green buildings have continuously increased across Chinese society. Although China's green building initiatives started about 30 years later than those of developed countries, the current technical level of green buildings in China is now on par with those of developed countries like the United States and Japan [48]. Since the release of ESGB 2019, more than 3200 projects have been evaluated, indicating its applicability in China. Table 3 compares the assessment projects of the new ESGB version. It shows that solar photovoltaics remain the mainstream renewable energy type in China's green buildings, and the three-star green buildings assessed by ESGB 2019 have seen improvements in building carbon emissions, indoor environment, and the proportion of green building materials compared to the previous version.

Moreover, the Chinese government has introduced related standards such as the "Design Standard for Energy Efficiency of Residential Buildings in Severe Cold and Cold Regions" [49] (JGJ26-2018) and the "Technical Standard for Nearly Zero Energy Buildings" [50] (GB/T51350-2019), playing an important role in promoting and developing zero-carbon buildings. The plan is to increase the area of ultra-low-energy and nearly zero-energy new buildings in China by more than 0.2 billion square meters above the 2023 level by 2025 [51,52]. Although the assessment scope of ESGB 2019 is smaller than CASBEE and LEED, it has improved green building performance. Meanwhile, China is promoting energy savings and carbon reduction in the construction industry through diverse energy-saving technologies and evaluation methods, contributing to the achievement of the "dual carbon" targets.

Table 3. Comparison of three-star public green buildings.

Project	**Dalian International Convention Center**	**University of Kitakyushu**	**Shenzhen Jinmao Community**	**Baoding City Design and Development Center**	**Yangzhou Science and Technology Innovation Building**	**Nanjing International Convention Center**
Standard	ESGB GB/T50378-2006 [53]	ESGB GB/T50378-2014 [54]	ESGB GB/T50378-2019 [55]	ESGB GB/T50378-2019 [55]	ESGB GB/T50378-2019 [55]	ESGB GB/T50378-2019 [55]
Rank	★★★	★★★	★★★	★★★	★★★	★★★
Floor Area (hm^2)	14.68	3.5	14.17	2.94	3.74	18.72
Climatic Region	Cold Region	Hot Summer and Cold Winter Zone	Hot Summer and Warm Winter Zone	Cold Region	Hot Summer and Cold Winter Zone	Hot Summer and Cold Winter Zone
Carbon Emissions During Operation	26.48 $kgCO_2/(m^2 \cdot a)$	18.48 $kgCO_2/(m^2 \cdot a)$	16.31 $kgCO_2/(m^2 \cdot a)$	20.16 $kgCO_2/(m^2 \cdot a)$	25.46 $kgCO_2/(m^2 \cdot a)$	26.26 $kgCO_2/(m^2 \cdot a)$
Indoor Air Pollutant Concentration	10.66% Higher Than the National Standard Limit	-	25% Below the National Standard Limit	20% Below the National Standard Limit	20% Below the National Standard Limit	20% Below the National Standard Limit
Ratio of Green Space	30%	41%	42.25%	28.79%	21%	15.45%
Green Building Materials Application Ratio	11.13%	15%	N/A	N/A	35%	30%
Utilization Rate of Non-Traditional Water Source	43.1%	100%	64.59%	N/A	54.27%	60%
Renewable Energy	Solar Photovoltaic	Solar Photovoltaic; Wind Power Generation	N/A	Solar Photovoltaic	Ground Source Heat Pump	Air Source Heat Pump; Solar Photovoltaic
Annual Runoff Total Control Rate	-	75.5%	71.65%	70%	70.49%	55%

In recent years, the global influence of the ESGB has also been steadily increasing. In 2018, the China Green Building Council assessed the dormitory building of the University of Kitakyushu in Japan based on ESGB 2014 and awarded it a three-star certification [56], the first ESGB application to an overseas building. As shown in Figure 3, the dormitory building of the University of Kitakyushu is located within the Kitakyushu Science and Research City in Japan, with a building area of 35,060 square meters, a height of 17 m, and four floors. The building had previously received an CASBEE S-rank certification.

Figure 3. School building of the University of Kitakyushu (Source: The University of Kitakyushu Official Website).

Table 4 shows the scoring details of this project based on ESGB 2014. The highest-scoring category was energy conservation and utilization, which aligns with the highest-scoring category in the CASBEE assessment. The project employs a centralized energy station, fan coil units, and a fresh air system for energy supply. It has a 160 kW internal combustion engine and a 200 kW fuel cell. While generating electricity, the waste heat is used to produce domestic hot water. When both devices operate at full capacity, they can produce approximately 5 tons of domestic hot water per hour, fully covering the demand for hot water. The comprehensive energy utilization exceeds 70%.

Table 4. Scoring details of school building of the University of Kitakyushu.

	Land Space 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**	**Operation Management**	**Improvement and Innovation**
Total Value	100	100	100	100	100	100	100	10
Evaluation Score	84	73	83	78	80	64	90	8
Weight Coefficient	0.13	0.23	0.14	0.15	0.15	0.10	0.10	1.00
Weighted Score	10.92	17.86	12.10	12.45	12.90	7.44	9.00	8
Total Points		90.68		Stars			★★★	

The project adopts a natural ventilation structure. Notably, "solar chimneys" are installed on the roof, utilizing the chimney effect induced by solar heat to promote natural ventilation. Additionally, the project sources air conditioning external air from an earth tube ventilation system, which pre-cools in summer and pre-heats in winter, potentially reducing carbon emissions by about 141 tons annually. The evaluation process for this project presented some operational challenges for the ESGB in an international context. Specifically, due to differing requirements and environmental conditions across countries, certain evaluation steps needed to reference Japanese energy efficiency standards instead of Chinese standards. This experience suggests that, for the ESGB to succeed internationally, it must incorporate flexible criteria that align with the regulatory frameworks and environmental priorities of host countries.

The broader international adoption of the ESGB faces challenges related to policy support, market incentives, and cultural adaptability. For instance, the green building incentive policies in European countries are more complex, incorporating tax credits and low-interest loans, which differ significantly from the current incentives in China [57]. The success of CASBEE and LEED can largely be attributed to supportive government policies and market-driven mechanisms. In Japan, for example, CASBEE emphasizes user comfort and integration with the local environment, receiving positive feedback from the real estate market. In Yokohama, for every 1% increase in CASBEE's environmental efficiency rating "BEE", the price per unit for new apartments can increase by approximately 5.5% [58]. The global rollout of LEED has benefited from its focus on decarbonization, improving quality of life and ecological conservation [59], with certified office buildings significantly reducing energy consumption and greenhouse gas emissions [60]. The United States has also been a pioneer in exploring climate-positive buildings, such as the Bullitt Center in Seattle, which achieved a carbon emission assessment of −30% in 2013 [61].

The integration of the ESGB with international initiatives like the Belt and Road Initiative provides opportunities for broader international application. Based on ESGB 2019, the China Urban Planning Society has engaged in "dual certification" collaborations with standards such as France's HQE, Germany's DGNB, and the UK's BREEAM, completing dual certification assessments for three overseas projects in 2019. China has also established the "International Multilateral Green Building Evaluation Standard" T/CECS 1149-2022 [62], which was officially implemented in 2023 and has already certified five overseas buildings. To effectively promote the ESGB internationally, strong policy support is still required. To enhance the ESGB's international influence, it is recommended to establish a more comprehensive support framework that includes rewards, subsidies, and effective incentive mechanisms to further encourage developer engagement. Additionally, integrating indicators that address user comfort and well-being can enhance ESGB's appeal across different cultural contexts.

Transparency is another crucial aspect for enhancing the ESGB's adaptability. Unlike USGBC and CASBEE, which regularly publish certified green building data and performance metrics, the ESGB has yet to establish a comparable level of information sharing. Improving the availability of information regarding evaluation processes, certified projects, and overall performance metrics could not only enhance the ESGB's credibility but also make it more appealing to international stakeholders looking to understand its benefits and potential to address global sustainability goals. Enhanced transparency could also provide a clearer understanding of how green buildings can support China in addressing climate challenges, meeting energy demands, and achieving sustainable development objectives. To meet the growing global demand for sustainable buildings, the ESGB has already achieved international application. By optimizing solutions to the aforementioned issues, the ESGB can better position itself as a viable standard for global green building assessment, contributing to sustainable development both in China and worldwide.

8. Conclusions

As China continues to advance its sustainable development agenda, the country is in the process of establishing a green building evaluation system that is both tailored to its national context and aligned with global standards. This study provides an in-depth examination of the development and revisions of the ESGB, followed by a comparative analysis of green building evaluation systems in China, Japan, and the United States across five key dimensions: outdoor environment, water conservation and utilization, energy efficiency, material conservation, and indoor environment. The results showed that the LEED evaluation system covers comprehensive sustainable development goals and continues to lead in new technologies and concepts. The CASBEE system, in contrast, emphasizes human-centered design and sustainable development, making adjustments that cater to local real estate markets. ESGB 2019 has optimized its indicator system and certification mode, improving its user-friendliness, ensuring the operational efficiency of green buildings in China, and expanding its international reach, gradually positioning itself as an internationally recognized standard.

Looking forward, several key areas require further exploration to enhance the ESGB's international competitiveness and relevance. Future research should focus on integrating emerging technologies, such as smart building management systems, carbon-neutral strategies, and renewable energy solutions, into the ESGB's framework. These technologies would not only elevate the ESGB's sustainability performance but also ensure its alignment with evolving global standards. Furthermore, cultural and regulatory factors must be explored to understand how the ESGB can be adapted to diverse international contexts. The adaptability of the ESGB to different regional environments, as well as its acceptance across cultural attitudes towards green building, will be critical to its global expansion. Pilot projects and cross-regional comparative studies will provide important insights into how the ESGB can expand its reach around the world.

In conclusion, this study makes contributions to the field of green building evaluation, offering a detailed comparison of the ESGB, LEED, and CASBEE, while identifying areas where the ESGB can be strengthened. The findings emphasize the importance of policy support, technological innovation, and cultural adaptation for the successful implementation of green building standards globally. These insights can guide future efforts to improve the ESGB, support the achievement of China's dual carbon goals, and contribute to the broader global sustainability.

Author Contributions: Conceptualization, Q.W.; methodology, Y.S.; formal analysis, Q.W.; resources, Q.W., Y.S., and Y.Z.; data curation, Y.S. and Y.Z.; writing—original draft, Q.W.; supervision, W.G. and Y.S.; project administration, W.G.; funding acquisition, Y.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

Acknowledgments: We would like to express our gratitude to all contributing authors for their dedication and invaluable input in the research and writing process. Their collective expertise and insights have greatly enriched the quality and depth of this manuscript. Thank you to each member for their commitment to this collaborative effort.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

ESGB	Evaluation Standard for Green Building in China
ESGB 2006	Evaluation Standard for Green Building in China (GB/T50378-2006)
ESGB 2014	Evaluation Standard for Green Building in China (GB/T50378-2014)
ESGB 2019	Evaluation Standard for Green Building in China (GB/T50378-2019)
LEED	Leadership in Energy and Environmental Design
LEED O+M v4.1	Leadership in Energy and Environmental Design: Operations + Maintenance v4.1
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
CASBEE-NC 2014	CASBEE for Building (New Construction) 2014 Edition
USGBC	U.S. Green Building Council
MOHURD	Chinese Ministry of Housing and Urban–Rural Development
HQE	Haute Qualité Environnementale
DGNB	Deutsches Institut für Baubiologie und Nachhaltigkeit
BREEAM	Building Research Establishment Environmental Assessment Method
N	Number of items
W	Index Weights
CI	Control Items
GI	General Items
SI	Scoring Items
OI	Optimal Items
AI	Additional Items

References

1. Zhang, Y.; Wang, H.; Gao, W.; Wang, F.; Zhou, N.; Kammen, D.M.; Ying, X. A survey of the status and challenges of green building development in various countries. *Sustainability* **2019**, *11*, 5385. [CrossRef]
2. Crawley, D.; Aho, I. Building environmental assessment methods: Applications and development trends. *Build. Res. Inf.* **1999**, *27*, 300–308. [CrossRef]
3. Illankoon, I.M.C.S.; Tam, V.W.Y.; Le, K.N.; Shen, L. Key credit criteria among international green building rating tools. *J. Clean. Prod.* **2017**, *164*, 209–220. [CrossRef]
4. Qiu, B. Review and prospect of green building in China. *Build. Energy Conserv.* **2019**, *47*, 1–4. (In Chinese)
5. Obata, S.H.; Agostinho, F.; Almeida, C.M.V.B.; Giannetti, B.F. LEED certification as booster for sustainable buildings: Insights for a Brazilian context. *Conserv. Recycl.* **2019**, *145*, 170–178. [CrossRef]
6. Gourlis, G.; Kovacic, I. Building information modelling for analysis of energy efficient industrial buildings–A case study. *Renew. Sustain. Energy Rev.* **2017**, *68*, 953–963. [CrossRef]
7. Jiru, T.E. Combining HVAC energy conservation measures to achieve energy savings over standard requirements. *Energy Build.* **2014**, *73*, 171–175. [CrossRef]
8. Doan, D.T.; Ghaffarianhoseini, A.; Naismith, N.; Zhang, T.; Ghaffarianhoseini, A.; Tookey, J. A critical comparison of green building rating systems. *Build. Environ.* **2017**, *123*, 243–260. [CrossRef]
9. Comprehensive Assessment System for Built Environment Efficiency (CASBEE) Home Page. [EB/OL]. [2017-04]. Available online: http://www.ibec.or.jp/CASBEE/english/ (accessed on 20 September 2024).
10. Haapio, A. Towards sustainable urban communities. *Environ. Impact Assess. Rev.* **2012**, *32*, 165–169. [CrossRef]
11. Zhang, D.; Wu, W.; Fang, P. Research on the development of green buildings in China. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *555*, 012095. [CrossRef]
12. Debrah, C.; Chan, A.P.C.; Darko, A. Green finance gap in green buildings: A scoping review and future research needs. *Build. Environ.* **2022**, *207*, 108443. [CrossRef]
13. Ritchie, H.; Roser, M. Annual CO_2 Emissions per Country [EB/OL]. Our World in Data. Available online: https://ourworldindata.org/grapher/annual-co2-emissions-per-country (accessed on 18 November 2024).
14. Berardi, U. A cross-country comparison of the building energy consumptions and their trends. *Conserv. Recycl.* **2017**, *123*, 230–241. [CrossRef]
15. Liu, K. Research on Low-Carbon Design of Tall Public Buildings in Hot Summer and Cold Winter Areas. Ph.D. Thesis, Southeast University, Nanjing, China, 2021. (In Chinese).
16. Shen, D. Comparison between LEED and green building evaluation standard certification system. *Constr. Sci. Technol.* **2018**, *6*, 40–43.
17. Su, Y.; Miao, Z.; Wang, C. The experience and enlightenment of Asian smart city development—A comparative study of China and Japan. *Sustainability* **2022**, *14*, 3543. [CrossRef]
18. Varma, C.R.S.; Palaniappan, S. Comparison of green building rating schemes used in North America, Europe and Asia. *Habitat Int.* **2019**, *89*, 101989. [CrossRef]
19. Remizov, A.; Tukaziban, A.; Yelzhanova, Z.; Junussova, T.; Karaca, F. Adoption of green building assessment systems to existing buildings under Kazakhstani conditions. *Buildings* **2021**, *11*, 325. [CrossRef]
20. Luangcharoenrat, C.; Intrachooto, S. Comparative analysis of green building rating standards for improvement opportunities. *Period. Polytech. Archit.* **2019**, *50*, 41–49. [CrossRef]
21. Stankovic, B.; Kostic, A.; Popovic, M.J. Analysis and comparison of lighting design criteria in green building certification systems-Guidelines for application in Serbian building practice. *Energy Sustain. Dev.* **2014**, *19*, 56–65. [CrossRef]
22. Aleem, S.H.E.A.; Zobaa, A.F.; Mageed, H.M.A. Assessment of energy credits for the enhancement of the egyptian green pyramid rating system. *Energy Policy* **2015**, *87*, 407–416. [CrossRef]
23. Zhang, Y.; Wang, J.; Hu, F.; Wang, Y. Comparison of evaluation standards for green building in China, Britain, United States. *Renew. Sustain. Energy Rev.* **2017**, *68*, 262–271. [CrossRef]
24. Lee, W.L. A comprehensive review of metrics of building environmental assessment schemes. *Energy Build.* **2013**, *62*, 403–413. [CrossRef]
25. Top, A.M.; Soyluk, A.; Ayçam, İ. Analytical Study on Reducing the Heating Effects of Daylight and Improving Natural Lighting Performance at Erzincan Train Station in the Context of Climate Change. *J. Daylighting* **2024**, *11*, 268–278. [CrossRef]
26. Gao, G. Research on Evaluation Standards of Green Buildings at Home and Abroad. Master's Thesis, Jilin Jianzhu University, Jilin, China, 2017. (In Chinese).
27. Nong, J.; Zhao, D.; Wei, R. Comparative analysis of the revision of water supply and drainage provisions in the 2019 edition of "Green Building Evaluation Standard". *Energy Conserv.* **2019**, *38*, 155–159. (In Chinese)
28. Ma, J.; Qian, Q.K.; Ye, Q.; Song, K.; Visscher, H.; Zhao, Q. New Development of China's National Evaluation Standard for Green Building (ESGB 2014): A Comparison of ESGB 2014 To ESGB 2006. In Proceedings of the Energy: Expectations and Uncertainty, 39th IAEE International Conference, Bergen, Norway, 19–22 June 2016; International Association for Energy Economics: Mount Royal, NJ, USA, 2016.
29. Wang, M.; Zhang, X.; Qin, X. A longitudinal and horizontal comparative study on the new version of green building evaluation standard in China. *J. Eng. Manag.* **2016**, *30*, 1–6. (In Chinese)

30. Han, H.; Yu, N. A comparative analysis of National green building evaluation standard and American LEED certification system in HVAC. *Refrig. Air Cond.* **2014**, *28*, 122–128. (In Chinese)
31. Yang, Y. Comparative analysis of Chinese and American green building evaluation systems. *Build. Mater. Decor.* **2019**, *36*, 86–87. (In Chinese)
32. Li, Y.; Mao, Y.; Wang, W.; Wu, N. Net-zero energy consumption building in China: An overview of building-integrated photovoltaic case and initiative toward sustainable future development. *Buildings* **2023**, *13*, 2024. [CrossRef]
33. Wang, Y.; Sigmund, O. Topology optimization of multi-material active structures to reduce energy consumption and carbon footprint. *Struct. Multidiscip. Optim.* **2024**, *67*, 5. [CrossRef]
34. Li, L.; Han, Y.; Li, Q.; Chan, W. Multi-dimensional economy-durability optimization method for integrated energy and transportation system of net-zero energy buildings. *IEEE Trans. Sustain. Energy* **2023**, *15*, 146–159. [CrossRef]
35. Wang, J.; Xu, T. Analysis of the latest revision of Singapore green mark green building evaluation standard. *South. Archit.* **2019**, *3*, 60–64. (In Chinese)
36. Jia, H.; Yu, W.; Zhang, M.; Li, Y.; Li, B. Comparison of green building evaluation standard system between China and Singapore. *Hvac* **2014**, *44*, 22–29. (In Chinese)
37. Li, L.; Li, Q.; Liu, J. Comparative analysis of green building evaluation standards in China, the United States and New Zealand. *Build. Energy Effic.* **2016**, *44*, 102–106+114. (In Chinese)
38. Yu, L.; Xu, B.; Hou, J. A comparative study of China's green building evaluation standards and British BREEAM. *South. Archit.* **2019**, *3*, 65–69. (In Chinese)
39. Ministry of Housing and Urban-Rural Development of the People's Republic of China. Announcement on the Release of the English Version of the 'Green Building Evaluation Standard' [EB/OL]. Available online: https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/202107/20210730_761399.html (accessed on 18 November 2024).
40. The Green Business Certification Inc (GBCI). GBCI China Report. [EB/OL]. [2023-05]. Available online: https://www.gbci.org/china (accessed on 14 October 2024).
41. Wang, L. Dalian Green Public Building Interior Physical Environment Based on POE Research. Master's Thesis, Dalian University of Technology, Dalian, China, 2019.
42. Yu, D.; Zhou, X.; Qi, H.; Qian, F. Low-carbon city planning based on collaborative analysis of supply and demand scenarios. *City Built Environ.* **2023**, *1*, 7. [CrossRef]
43. US Green Building Council (USGBC). Advancing Green Infrastructure Through Policy. [EB/OL]. [2023-08]. Available online: https://www.usgbc.org/articles/advancing-green-infrastructure-through-policy (accessed on 14 October 2024).
44. Suzuki, Y.; Tanaka, Y.; Yoshino, R.; KOBAYASHI, K. Efforts on environmental impact assessment using LCA in the construction sector. *J. Jpn. Soc. LCA* **2023**, *19*, 25–32. (In Japanese)
45. Improve the quality level of green buildings and promote the high-quality development of green buildings—The relevant person in charge of the standard quota department of the ministry of housing and construction interprets the new version of green building evaluation standards. *China Surv. Des.* **2019**, 6–7. (In Chinese)
46. US Green Building Council (USGBC). LEED v5 is the Next Version of the Globally Recognized Comprehensive Framework for Green Building Practices. [EB/OL]. [2024-05]. Available online: https://www.usgbc.org/leed/v5 (accessed on 14 October 2024).
47. Japan Sustainable Building Consortium (JSBC). Opening of New Building (Trial Version in 2024) and Solicitation of Opinions. [EB/OL]. [2024-08]. Available online: https://www.jsbc.or.jp/research-study/casbee/tools/cas_nc.html (accessed on 14 October 2024).
48. Chinese Society for Urban Studies. Adhere to the People-Centered Development Concept and Promote the High-Quality Development of Green Buildings. [EB/OL]. [2024-05]. Available online: https://www.chinasus.org/index.php?c=content&a=show&id=1202 (accessed on 14 October 2024). (In Chinese).
49. *JGJ 26-2018*; Design Standard for Energy Efficiency of Residential Buildings in Severe Cold and Cold Regions. China Architecture & Building Press: Beijing, China, 2018.
50. *GB/T 51350-2019*; Technical Standard for Nearly Zero Energy Buildings. China Architecture & Building Press: Beijing, China, 2019.
51. Wei, J.; Li, J.; Zhao, J.; Wang, X. Hot topics and trends in zero-energy building research—A bibliometrical analysis based on CiteSpace. *Buildings* **2023**, *13*, 479. [CrossRef]
52. State Council of the People's Republic of China. Notice of the General Office of the State Council on Forwarding the "Work Plan for Accelerating Energy Conservation and Carbon Reduction in the Construction Sector" by the National Development and Reform Commission and the Ministry of Housing and Urban-Rural Development [EB/OL]. Available online: https://www.gov.cn/zhengce/zhengceku/202403/content_6939607.htm (accessed on 18 November 2024).
53. *GB/T 50378-2006*; Green Building Evaluation Standard. China Architecture & Building Press: Beijing, China, 2006.
54. *GB/T 50378-2014*; Green Building Evaluation Standard. China Architecture & Building Press: Beijing, China, 2014.
55. *GB/T 50378-2019*; Green Building Evaluation Standard. China Architecture & Building Press: Beijing, China, 2019.
56. China Society for Urban Studies Green Building Research Center [EB/OL]. Available online: https://www.csus-gbrc.org/ (accessed on 18 November 2024).
57. Xu, S. International comparison of green credit and its enlightenment to China. *Green Financ.* **2020**, *2*, 75–99. [CrossRef]
58. Takata, H.; Yoshida, Y.; Kawakubo, S.; Yamaguchi, A. Influence of environmental performance on the selling price and used transaction price of apartment houses: Empirical analysis using CASBEE Yokohama evaluation re-sults. *J. Environ. Eng.* **2020**, *85*, 89–95. [CrossRef]

59. U.S. Green Building Council. A Guide to LEED v5: Overview and Addressing Decarbonization [EB/OL]. Available online: https://www.usgbc.org/education/sessions/guide-leed-v5-overview-and-addressing-decarbonization-12857220 (accessed on 18 November 2024).
60. Scofield, J.H.; Brodnitz, S.; Cornell, J.; Liang, T.; Scofield, T. Energy and greenhouse gas savings for LEED-Certified US office buildings. *Energies* **2021**, *14*, 749. [CrossRef]
61. Bullitt Foundation. The Bullitt Center Generated 30% More Energy Than it Used in Its First 10 Years [EB/OL]. [2023-04]. Available online: https://bullittcenter.org/2023/04/20/net-positive-energy-over-first-decade/ (accessed on 14 October 2024).
62. *T/CECS 1149-2022*; International Multilateral Green Building Evaluation Standard. China Association for Engineering Construction Standardization: Beijing, China, 2022.