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A comparative research of Assessment standard for green building in China

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Abstract

Green building gradually becomes a development trend in the construction industry, and green building assessment standards play a guiding and promoting role for green buildings. Therefore, countries have begun to issue and promote green building assessment standards, continuing to improve and improve in practice. Taking ASGB 2019 (China) and LEED v4.1 (USA) as the research objects, this paper mainly conducts a longitudinal and horizontal comparative analysis of ASGB 2019, compares the framework structure, calculation method and specific content of various provisions, and summarizes the similarities and differences between them. First of all, the specific content and provisions of the latest versions of the two standards are introduced. The content of each article is analyzed separately. Secondly, the old and new ASGB standards (2014 and 2019) are compared, and the similarities, differences and reasons for changes are analyzed. After that, the two latest standards of ASGB 2019 and LEED v4.1 were compared and analyzed. The similarities and differences in the framework structure, scoring methods and other aspects between the two versions are analyzed. The specific evaluation content of the two standards is further compared to find similarities and differences between the two standards and the analysis is summarized. Finally, summarize and propose amendments to the ASGB standard from the summary.

Keywords: green building; Assessment standard for green building; LEED; comparative study.

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Chapter 1

Introduction

1.1 Research background

Global greenhouse gas emissions have triggered a series of problems, including social issues, global warming and energy supply shortages, so people's awareness and voice for green sustainable development is getting higher and higher, leading to widespread concern for green development by governments and societies around the world [1]. As one of the three basic industries with huge energy consumption, the construction industry has been criticized as the main consumer of energy and natural resources, consuming more than 30% of the world's resources, greenhouse gas emissions account for more than one-third of the total global emissions [2]. With the large consumption of resources, the development of the construction industry has produced a series of environmental problems, which has aroused public concern, and sustainable and healthy development has become more and more important. As a result, the green development of the construction industry came into being.

1.1.1 An overview of the definition and development of green buildings

Since the 1960s, building practitioners from all over the world have successively proposed energy-saving buildings, ecological buildings and green buildings, advocating the application of renewable energy in buildings and the concept of environmentally friendly buildings. The brief development context of green buildings is shown in the Figure1.1. Over the past few decades, green buildings have gradually developed from a single green building technology to a single green building until the green building system, Scholars' research on the relevant factors of green buildings is also more and more extensive.

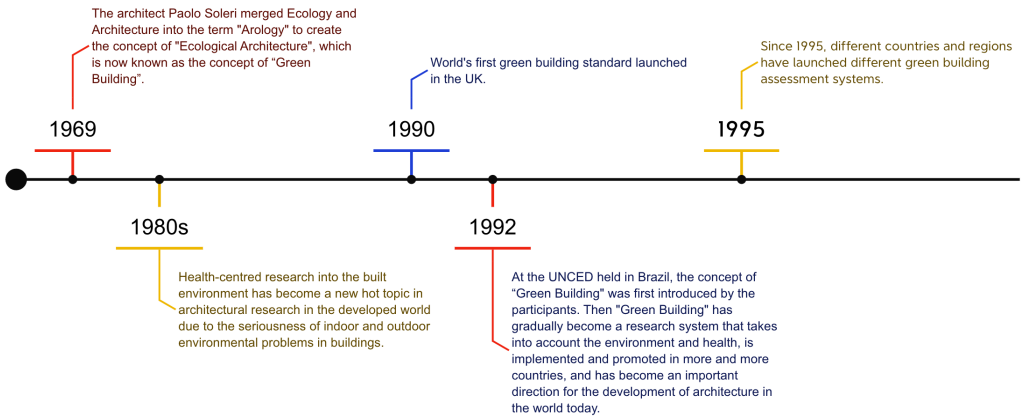


Figure 1.1: The brief development context of green building.(source: author's elaboration)

In the course of its development, institutions in many countries have offered a wealth of insights into green buildings. The U.S. Environmental Protection Agency defines "green building" as:" Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction.[3]". The World GBC

defines “green building” as “A ‘green’ building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life.[4]”. The BSRIA (Building Services Research and Information Association) in the UK defines “green building” as: “ GREEN BUILDINGS, WHICH CAN ALSO be called ‘green construction’ or ‘sustainable building’ means designing and operating buildings in ways that are environmentally friendly and economical of resources.[5]”. This definition is defined from the perspective of building construction and management, emphasizing resource efficiency and ecological principles as well as the requirements of a healthy environment. China has proposed the definition of “green building” in the “Assessment standard for green building” which has been supplemented and modified after revision of the version, and the latest “Assessment standard for green building” (GB/T 50378-2019) released in 2019 defines ”green building” as “The high-quality building that is able to save the resources, protect the environment and reduce pollution to provide people with a healthy, applicable and efficient space and maximally realize harmonious coexistence with the nature during its whole life cycle.[6]”. Overall, there are differences between countries in terms of how green buildings are described, but all generally agree on three themes: efficient use of resources, creating a healthy and comfortable living environment, and living in harmony with the surrounding environment.

1.1.2 Introduction to the Green Building Rating System

The assessment standard of green building is born by the specification and implementation of the concept of green building, from the perspective of the first green building assessment standard (BREEAM) established in the United King-

dom, mainly through objective quantitative indicators such as the energy saving rate in green buildings, water saving rate, energy saving and reduction, the use of raw materials guides the architectural design and the development of green buildings. Since there are different factors, green buildings need to be considered when conducting assessments in different places; And the same factors vary greatly under different regional resources and humanistic requirements; At the same time, the application of green technology will also vary depending on the type of building. So, different countries and regions will formulate green building assessment standards according to local conditions. It is not difficult to understand that one of the basic concepts of green building is applicable to regional geography, climate, economy, etc., and there are so many countries and regions in the world, that these elements are different in various countries and regions. The UK's BREEAM is the world's first systematic green building assessment standard, followed by numerous green building assessment systems.

Date of publication	Region	Assessment Standard
1990	UK	BREEAM(Building Research Establishment Environmental Assessment Method)
1996	Hong Kong	HK-BEAM(Hong Kong Building Environmental Assessment Method)
1998	Canada	GBTool(Green Building Challenge)
1998	USA	LEED(Leadership in Energy & Environmental Design Building Rating System)
2000	Sweden	EcoEffect
2001	Australia	NABERS(National Australian Built Environment Rating System)
2002	France	HEQ(high Environmental Quality)
2002	Japan	CASBEE(Comprehensive Assessment System for Building Environmental Efficiency)
2005	South Africa	SBAT(Sustainable Building Assessment Tool)
2006	Netherlands	Eco-Quantum
2006	China	ASGB(Assessment Standard for green building)

Table 1.1: Green building assessment systems in different countries and regions.(source: author's elaboration)

Among the many standards, the LEED standard in the United States has great reference value and is the most extensive green building system in the world. Australia, France, Italy, Japan, India, and other countries, including China, have conducted extensive and in-depth research and application of LEED.

1.2 Research objects and methods

1.2.1 Research objects

Assessment standard for green building (ASGB)

In 2006, the Ministry of Housing and Urban-Rural Development of the People's Republic of China issued GB/T50378-2006 "Assessment standard for green building" (ASGB 2006), which has been updated twice to 3 forms. GB/T50378-2019 Assessment standard for green building (ASGB) implemented on August 1, 2019, is the latest version of the green building operation and maintenance assessment system in China, which is the main research object of this thesis.

LEED v4.1

The US Green Building Council (USGBC) introduced the LEED 1.0 Pilot version in 1998. LEED has since been updated in several versions, with the latest version of LEED v4.1 released in March 2018 as the second object of this thesis. This thesis is primarily based on LEED v4.1 BD+C (New Construction) as a specific analytical research object.

1.2.2 Research Methods

Study the development and change of China's green building standards from the change of assessment standards on the time axis, and conduct detailed comparative analysis of ASGB 2019 and ASGB 2014 versions. Among them, the main

analysis and research are the changes in its content and score.

Compare LEED v4.1 (taking BD+C Construction as an example) to the ASGB 2019 assessment system in China, and the main analysis is carried out from the perspective of assessment standards. The relative significance index (RSI) of specific index items in the two assessment systems is mainly analyzed, and the subjective judgment is transformed into an objective value comparison. The content of specific items will also be compared. This thesis will try to conduct research and analyze the advanced and shortcomings of those standards and make some targeted suggestions

Chapter 2

LEED standard

2.1 Background

2.1.1 Background of the times

The "energy crisis" that the United States experienced between the 1960s and 1970s made Americans aware of the "finiteness" of energy. The tragic facts and the unremitting propaganda of scientists have made "protecting the earth, saving energy and environmental protection" a topic that everyone in the United States is concerned about.

The US Green Building Council (USGBC) has taken on the responsibility of standardizing green building orientation in order to meet the needs of the domestic building market for green buildings and green building assessment, improve the economic performance and energy conservation and environmental protection of buildings. After 5 years of research, in 1998 USGBC successfully developed LEED v1.0 and began pilot testing of 19 projects. LEED NC(LEED for New Construction) held a public launch ceremony in March 2000, which is also the

earliest version of the LEED system in the United States, mainly for offices and commercial buildings

2.2 Historical version

From the first LEED version LEED v1.0 promulgation begins, LEED upgraded every once in a while. In 2001 the version was LEED v2.0. In the subsequent development of the assessment system, LEED NC was Constantly revised and updated (NC2.1 and NC2.2). That subsequently updated NC2.1, NC2.2 and LEED v2.0 kept unchanged on the scoring system framework. Improvements have been made only in the specification of the indicator for technical updates.

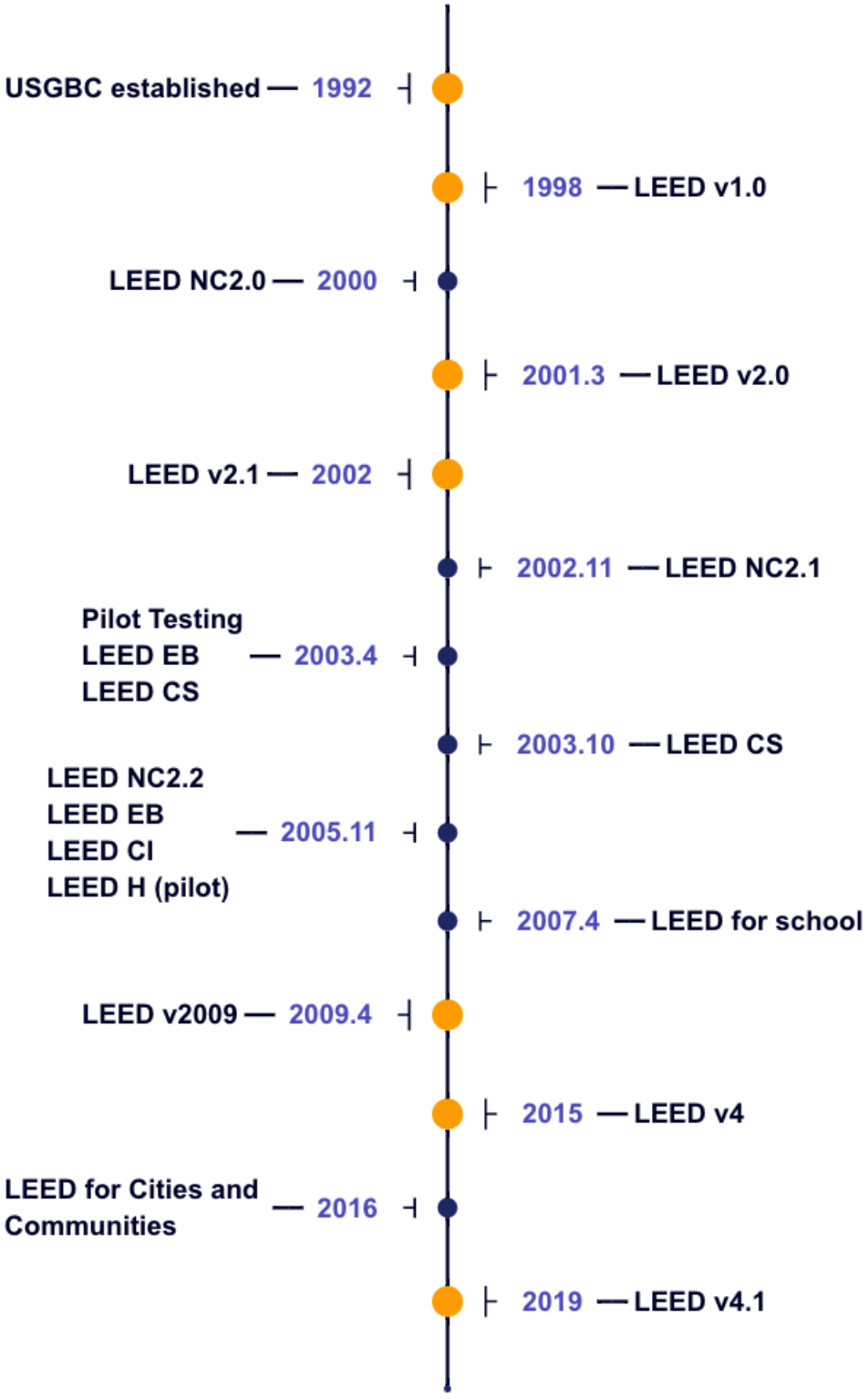


Figure 2.1: Evolution of LEED assessment system[13,14,15]

In the nearly 20 years since its birth and development, LEED has been constantly enriching and improving itself, and in the alternate time interval between the old and new versions, it will also develop and promulgate new family members to improve and broaden the assessment object and scope of LEED. Table 2.1 lists the main nodes in the evolution of LEED, Where LEED v4.0 is a node that adjusts the assessment object more.

Time	Edition	Highlight
1998	LEED v1.0	In 1998, the USGBC, the U.S. Green Building Council, successfully released LEED v1.0 and began pilot testing 19 projects. Following the success of the pilot project, LEED for New Construction for new buildings was publicly launched in March 2000
2001	LEED v2.0	In March 2001, based on the experience of the pilot project, LEED v2.0 was introduced in the United States. In November 2002, a junior high school in Stetsville was rated for the first time LEED Gold. USGBC further went into new market sectors. At the same time, in response to the boom and demand of the green building industry, the USGBC held the first International Conference and Expo on Green Building in Austin, Texas in the same month.

Time	Edition	Highlight
2003	LEED EB LEED CS	In 2003, there were some major developments in LEED. USGBC grew from the beginning as a fledgling nonprofit, amassing strength, staff, and resources, and launched LEED v2.1 the previous year. LEED for existing buildings in April 2003 and commercial Interiors began pilot trials. LEED for Core and Shell was released in October.
2009	LEED v2009	USGBC launched LEED v2009 in April 2009. Based on the previous LEED v2.2, LEED v2009 introduced weights based on TRACI of the Environmental Protection Agency as well as the National Institute of Standards. This progress has made LEED tend to be more rigorous and specify which points are the most important.
2015	LEED v4.0	LEEDv4.0 came out in 2015 and features many new improvements over the previous system, including increased flexibility, performance-based smart grid approach, emphasis on materials and resources, comprehensive water treatment methods, as well as simplified documentation. LEED-v4 continues to raise the bar for green buildings.

Time	Edition	Highlight
2019	LEED v4.1	LEED v4.1 is available for all versions – it contains updated reference standards and allows projects to get permission points by building performance monitoring. It also continues to drive performance, fully integrating performance results supported by new methodologies and simple data-driven paths to continuously measure performance.

Table 2.1: The main evolution nodes of LEED[13,14,15]

2.3 LEED v4.1

LEED, full name is Leadership in Energy and Environmental Design, is a Assessment standard green building that can be used worldwide by the USGBC in the United States. First published in 1998 and the latest in 2019, LEED is the world's most widely used and popular Assessment standard green building.

2.3.1 Assessment Object

Since the establishment of the USGBC, LEED assessment objects have gradually covered various types of buildings, and the scope of assessment has gradually covered the different life cycle stages of buildings. This is shown in Table 2.2.

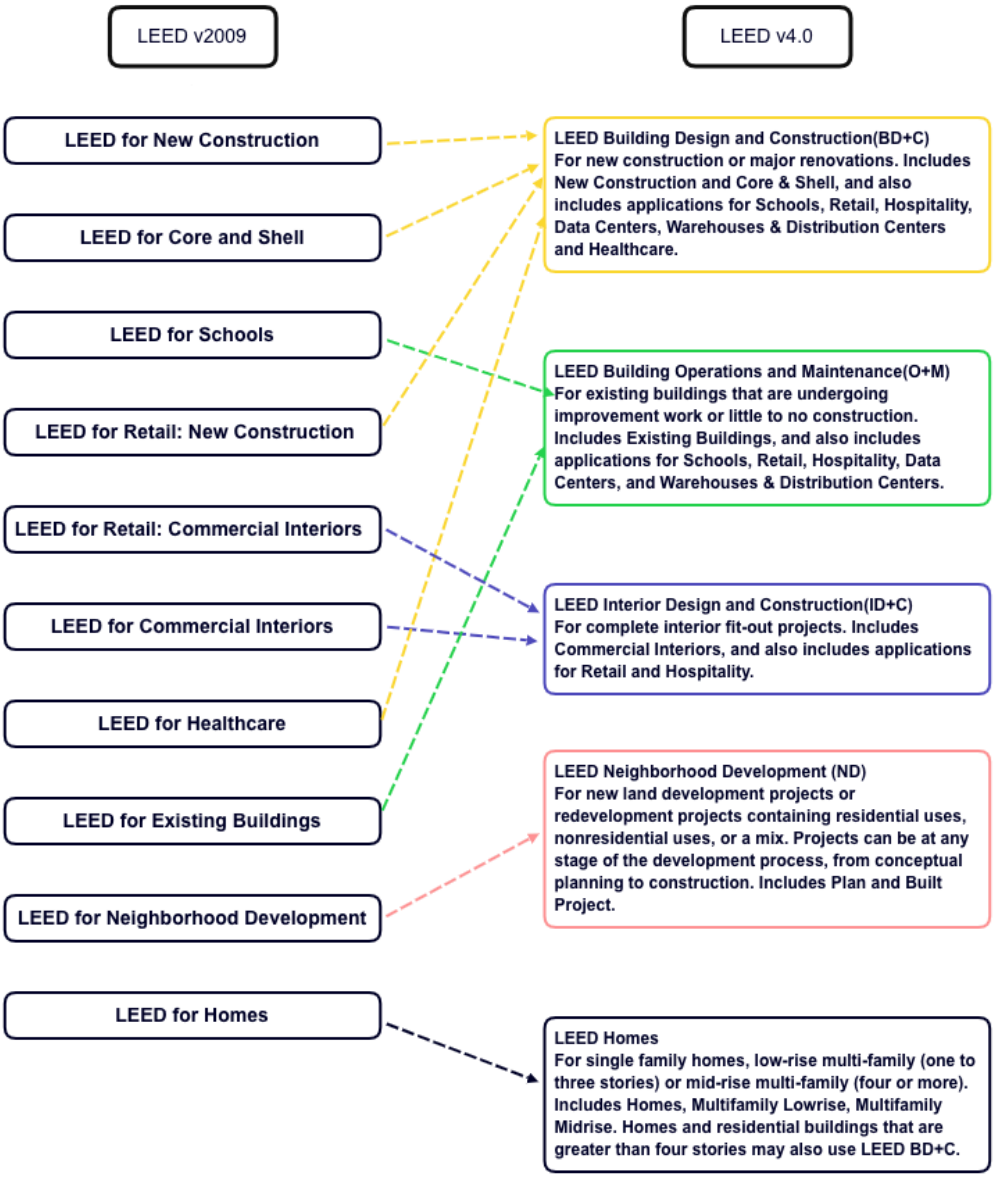


Figure 2.2: The corresponding relationship between LEED 2009 and LEED v4.0[7]

BD+C Building Design and Construction	This rating system is for new construction or major renovations. Includes: • New Construction • Core & Shell • Schools • Retail • Hospitality • Data Centers • Warehouses & Distribution Centers • Healthcare.
Residential	Residential BD+C addresses residential buildings that are new construction or major renovation. Includes: • Single Family Homes • Multifamily Homes • Multifamily Homes Core and Shell
ID+C Interior Design and Construction	This rating system is for interior spaces that are a complete interior fit-out Includes: • Commercial interiors • Retail • Hospitality
O+M Operations and Maintenance	This rating system is for buildings & spaces that are fully operational and occupied for at least one year. Includes: • Existing Buildings • Existing Interiors
Cities and Communities	LEED v4.1 expands the solutions for LEED for Cities and LEED for Communities. Includes: • Plan and Design • Existing

Table 2.2: LEED v4.1 Assessment object and scope[7]

2.3.2 Assessment system

The LEED v4.1 assessment system consists of nine categories and a number of items, mainly from the Integration Process, Location and Transportation, Sustainable Site, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation and Regional Priority of the building to conduct a comprehensive investigation, evaluate its impact on the environment, and score according to the indicators of each aspect. The total score is 110 points, and the building assessment is based on the cumulative sum of the scores of the project in each section, and the grade is awarded in the range of the total points obtained, which is divided into four certification levels. There is no weight coefficient in the LEED v4.1 standard, and the importance of each part is reflected in the proportion of the score of that part.

LEED v4.1 certification level	point requirement
Platinum	80+ points earned
Gold	60-79 points earned
Silver	50-59 points earned
Certified	40-49 points earned

Table 2.3: LEED v4.1 Certification Levels[7]

2.4 LEED v4.1 Detailed explanation of the BD+C standard

Because the assessment object and assessment scope of LEED are very broad, this item only selects the standard of LEED v4.1 BD+C for detailed analysis and understanding, and the New Construction standard has been selected for subsequent comparative analysis. LEED BD+C, full name is LEED Building Design and Construction, is an assessment object involving 8 building types.

2.4.1 Assessment logic

The assessment logic of the LEED standard is quite simple and convenient, there is no weight system. The total value of the score of each part replaces the weight as a scalar to show the importance. The building green grade assessment is carried out by the score of each part and the grade interval.

	IP	LT	SS	WE	EA	MR	EQ	IN	RP
New Construction	1	16	10	11	33	13	16	6	4
Core and Shell	1	20	11	11	33	14	5	6	4
Schools	1	15	12	12	31	13	16	6	4
Retail	1	16	10	12	33	13	15	6	4
Data Centers	1	16	10	11	33	13	16	6	4
Warehouses and Distribution Centers	1	16	10	11	33	13	16	6	4
Hospitality	1	16	10	11	33	13	16	6	4
Healthcare	1	9	9	11	35	19	16	6	4
Note: Integrative Process(IP); Location and Transportation(LT); Sustaninable Sites(SS); Water Efficiency(WE); Energy and Atmosphere(EA); Materials and Resources(MR); Indoor Environmental Quality(EQ); Innovation(IN); Regional Priority(RP)									

Table 2.4: LEED BC+C Scorecard for each type[8]

2.4.2 Assessment Object

The LEEDv4.1 BD+C assessment object, which follows the LEED v4.0 version, is composed of the original LEED 2009 fusion, a total of 8 types of buildings (or combination of buildings), namely: New Construction, Core and Shell, Schools, Retail, Data Centers, Warehouses and Distribution Centers, Hospitality and Healthcare.

2.4.3 Assessment content

The names of the assessment categories and items in LEED v4.1 BD+C are shown in Table 2.5, the grey ones are the prerequisite items.

2.4.4 Analysis of LEED v4.1 BD+C(NC)

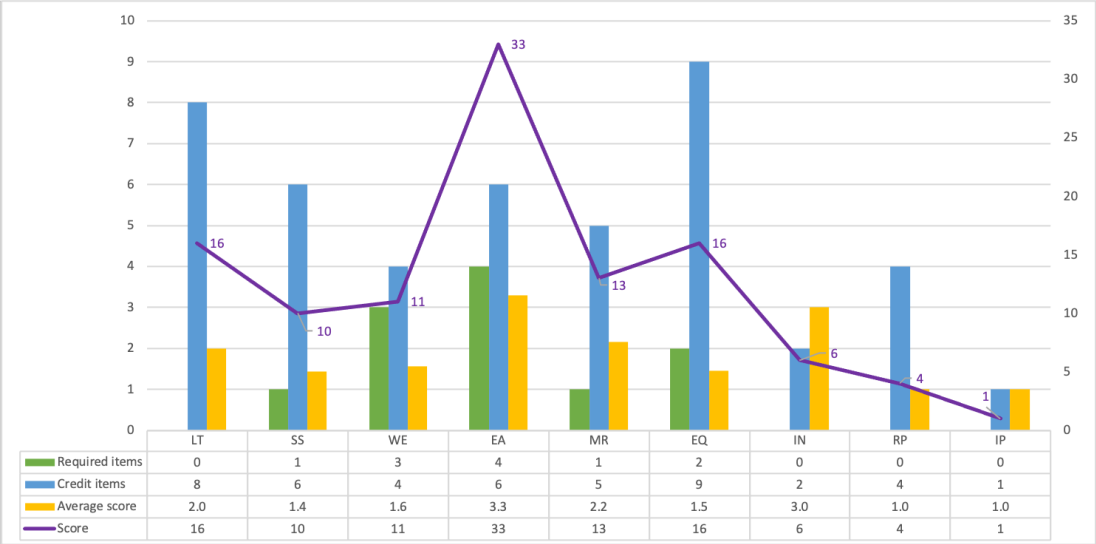
Respectively the prerequisite items, scoring items and score values of LEED v4 1 BD+C (New Construction) are analyzed, their specific gravity is calculated, and the different proportions of different categories are compared for analysis. The analysis of Indoor Environmental Quality, Location and Transportation, Water Efficiency, Energy and Atmosphere, Material and Resources, Sustainable sites,Integration Process, Innovation and Regional priority is analyzed in Table 2.6, For further statistical analysis, see Figures 2.3 and 2.4

Integrative Process(LP)	Integrative Project Planning and Design (Only applies to Healthcare)
	Integrative Process
Location and Trasportation(LT)	LEED for Neighborhood Development Location
	Sensitive Land Protection
	High Priority Site and Equitable Development
	Surrounding Density and Diverse Uses
	Access to Quality Transit
	Bicycle Facilities
	Reduced Parking Footprint
	Electric Vehicles
Sustainable Sites(SS)	Construction Activity Pollution Prevention
	Environmental SiteAssessment (Only applies to Schools and Healthcare)
	Site Assessment
	Protect or Restore Habitat
	Open Space
	Rainwater Management
	Heat Island Reduction
	Light Pollution Reduction
	Site Master Plan((Only applies Schools)
	Tenant Design and Construction Guidelines (Only applies to Core & shell)
	Places of Respite (Only applies to Healthcare)
	Direct Exterior Access (Only applies to Healthcare)
	Joint Use of Facilities (Only applies to Schools)
Water Efficiency(WE)	Outdoor Water Use Reduction
	Indoor Water Use Reduction
	Building-Level Water Metering
	Outdoor Water Use Reduction
	Indoor Water Use Reduction
	Optimize Process Water Use
	Water Metering
Energy and Atmosphere(EA)	Fundamental Commissioning and Verification
	Minimum Energy Performance
	Building-Level Energy Metering
	Fundamental Refrigerant Management
	Enhanced Commissioning
	Optimize Energy Performance
	Advanced Energy Metering
	Grid Harmonization
	Renewable Energy
	Enhanced Refrigerant Management
Materials and Resources(MR)	Storage and Collection of Recyclables
	PBT Source Reduction - Mercury (Only applies to Healthcare)
	Building Life-Cycle Impact Reduction
	Building Ptoduct Disclosure and Optimization - Environmental Product Declarations(EPD)
	Building Ptoduct Disclosure and Optimization - Sourcing of Raw Materials
	Building Ptoduct Disclosure and Optimization - Material Ingredients
	PBT Source Reduction – Mercury (Only applies to Healthcare)
	PBT Source Reduction – Lead, Cadmium, and Copper (Only applies to Healthcare)
	Furniture and Medical Furnishings (Only applies to Healthcare)
	Design for Flexibility (Only applies to Healthcare)
	Construction and Demolition Waste Management
Indoor Environmental Quality(EQ)	Minimum Indoor Air Quality Performance
	Environmental Tobacco Smoke Control
	Minimum Acoustic Performance (Only applies to Schools)
	Enhanced Indoor Air Quality Strategies
	Low-Emitting Materials
	Construction Indoor Air Quality Management Plan
	Indoor Air Quality Assessment (Not apply to Core & Shell)
	Thermal Comfort (Not apply to Core & Shell)
	Interior Lighting (Not apply to Core & Shell)
	Daylight
	Quality Views
	Acoustic Performance (Not apply to Core & Shell and Retail)
Innovation(IN)	Inovation
	LEED Accredited Professional
Regional Priority(RP)	Regional Priority

Table 2.5: LEED v4.1 DB+C Categories and Items[8]

		New Construction						
		Required items	Credit items	Total items	Score	Average score	Weighting (%)	Total score
Location and Trasportation	LT	0	8	8	16	2	14.5454545	110
Sustainable Sites	SS	1	6	7	10	1.42857143	9.09090909	
Water Efficiency	WE	3	4	7	11	1.57142857	10	
Energy and Atmosphere	EA	4	6	10	33	3.3	30	
Materials and Resources	MR	1	5	6	13	2.16666667	11.8181818	
Indoor Environmental Quality	EQ	2	9	11	16	1.45454545	14.5454545	
Innovation	IN	0	2	2	6	3	5.45454545	
Regional Priority	RP	0	4	4	4	1	3.63636364	
Integrative Process	IP	0	1	1	1	1	0.90909091	

Table 2.6: Summary of LEED v4.1 DB+C(NC)(source: author's elaboration)



	LT	SS	WE	EA	MR	EQ	IN	RP	IP
Required items	0	1	3	4	1	2	0	0	0
Credit items	8	6	4	6	5	9	2	4	1
Average score	2.0	1.4	1.6	3.3	2.2	1.5	3.0	1.0	1.0
Score	16	10	11	33	13	16	6	4	1

Figure 2.3: Summary analysis of LEED v4.1 BD+C(NC)(a).(source: author's elaboration)

Figure 2.4: Summary analysis of LEED v4.1 BD+C(NC)(b).(source: author's elaboration)

From the chart, it can be seen that LEED is primarily concerned about and controls the use of energy and the impact on the atmosphere of the building, whether it is the number of prerequisite items, the total assessment score, or the proportion are in the first place, reflecting the all-round control and attention to it. Secondly, the consideration of the indoor environment, which accounts for the same score as the site selection and traffic. But is more detailed and more rigorous in the number of scoring points, which is more difficult to score. In the other three, the choice of sustainable sites is relatively weak, while the control of materials and resources is relatively important. It can be roughly summarized from LEED v4.1 that the USGBC organization in the United States believes that the most serious problems at this stage are energy and atmospheric problems, followed by indoor environmental quality, location and transportation, materials and resources, water efficieny, and sustainable sites, decreasing in order of importance.

Chapter 3

China Green Building Standard ASGB

3.1 Background and development

3.1.1 Background

Since the 1990s, the world is facing pressing problems such as energy shortage and environmental pollution. Countries have favoured the concept of energy conservation and emission reduction and green development of buildings, and have formulated relevant assessment systems. China has kept pace with the times, and in 2005 it set its sights on promoting green buildings and formulated and implemented relevant building assessment guidelines.

3.1.2 Historical versions

Since the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, the Chinese government has successively promulgated a number of relevant outlines, guidelines and regulations to vigorously promote the

development of green buildings. The 2006 version of the Assessment standard green building issued by the Ministry of Housing and Urban-Rural Development is the first comprehensive national green building standard in China, which establishes an evaluation system with "four saving and one protection" at its core. After the release of this standard, the original corresponding local standards and Assessment standard green buildings for some special buildings on this basis have been gradually revised and improved. With the development of green buildings and green technologies, the Assessment standard green building was first updated on April 15, 2014, and on January 1st 2015 Officially implemented. The revision added construction management content on the basis of the 2006 version, restricting the reduction of loss and pollution in the construction process. After 5 years of implementation of the 2014 edition of the Assessment standard green building, the proportion of buildings with operating labels in the overall green building is still not much, and the user's perception of green performance needs to be improved. To solve the above problem, a new revision was made in 2019. The 2019 version of the Assessment standard green building released in 2019 was officially implemented on August 1st, 2019, from the original conservation of energy, land, water and resources upgraded to maintain the conservation of resources while making requirements and regulations on the comfort and economy of the building.

	ASGB 2006	ASGB2014	ASGB2019
The version number	GB/T50378-2006	GB/T50378-2014	GB/T50378-2019
Assessed object	• Residential buildings; •Public buildings in office buildings, shopping malls and hotel buildings	• Residential buildings • Public buildings (no more limited in scope).	• Residential buildings • Public buildings
Assessement stage	The post-2008 revision distinguishes between "Design Assesment" and "Operational Assesment"	• Design and construction stage (Design Label) • Completed and put into use (Operational Label).	There are pre-assessment and assessment. The pre-assessment shall be carried out after the examination and approval of the construction drawings and design documents of the construction project. The assessment shall be carried out after the completion of the construction project.
Assessment index system	• 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 • Operation Management	• 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 • Operation Management	• Safety and Durability • Health and Comfort • Occupant Convenience • Resource Saving • Environment Livability
Bonus items	none	In addition to the scoring items, the bonus items " Promotion and Innovation " are set separately, and the score is capped at 10 points. "Performance Improvement' focuses on technical performance improvements such as energy efficiency and environmental protection. "Innovation" has no specific target requirements, but only provides direction and encourages the adoption of innovative technologies or management.	In addition to the scoring items, the bonus items " Promotion and Innovation " are set separately, and the score is capped at 10 points.
Rating	Number counting legal level (each indicator has no weight). That is, the number of items that meet a certain level is reached.	Score counting legal level (each indicator has weights) ★$50 \leq \sum Q < 60$ ★★$60 \leq \sum Q < 80$ ★★★$80 \leq \sum Q$	Score counting legal level (each index has weights) basic level: meet all control items ★$60 \leq \sum Q < 70$ ★★$70 \leq \sum Q < 85$ ★★★$85 \leq \sum Q$

Table 3.1: The development of the ASGB version[6,9,10]

3.2 ASGB 2019

ASGB 2019 updated the definition of green building as A high-quality building that is able to save resources, protect the environment and reduce pollution to provide people with a healthy, applicable and efficient space and maximally realize harmonious coexistence with nature during their whole life cycle (Item 2.0.1 of ASGB 2019)[6]. Based on the original definition, more emphasis is placed on the feeling of the living subject of green buildings, which to a certain extent indicates the development direction of green buildings in China at this stage.

3.2.1 Classification of assessment levels

The ASGB 2019 shall take a single building or a group of buildings as the assessed object (Item 3.1.1 of ASGB2019). The assessment takes place after the construction work is completed. After the construction drawing design of the building project is completed, a pre-assessment can be carried out (Item 3.1.2 of ASGB2019). It can effectively restrain the advancement and execution of green building technology. The ASGB 2019 consist of five basic indicators of Safety and Durability, Health and Comfort, Occupant Convenience, Resource Saving, and Environment Livability, as well as a bonus Category of Promotion and Innovation. Each type of basic index includes prerequisite items and scoring items (Item 3.2.1 of ASGB 2019). The assessment result of the prerequisite items is whether they meet the standard or not (400 points for meeting the standard), and the scoring and extra points are the corresponding points (Item 3.2.2 of ASGB2019). When the extra points score is greater than 100 points, it will be taken as 100 points (Item 9.1.2 of ASGB 2019). Total score = add all scores / 10.

Scores of Green Building Assessment							
	Basic score for prerequsite items	Full score of scoring items for assessment index					Full score of bonus items for promotion and innovation
		Safety and durability	Health and comfort	Occupant convenience	Resources saving	Environment livability	
Pre-assessment score	400	100	100	70	100	100	100
Assessment score	400	100	100	100	100	100	100
Note: No score for articles 6.2.10, 6.2.11, 6.2.12, 6.2.13, and 9.2.8 of this standard in pre-assessment.							

Table 3.2: Scores of ASGB 2019[6]

Green buildings are divided into four grades: basic, one-star, two-star, and three-star (Item 3.2.6 of ASGB 2019). All green buildings should meet all standard requirements of prerequisite items and different star ratings should also meet different technical requirements. The basic level is deemed to satisfy all prerequisite items (Item 3.2.7 of ASGB 2019), with a total score of 60 points, 70 points and 85 points corresponding to one-star, two-star and three-star respectively (Item 3.2.8 of ASGB 2019).

	One-star grade	Two-star grade	Three-star grade
The ratio of improvement of thermal performance of building envelope, or the ratio of reduction of load of building heating and air conditioning	The thermal performance in building envelope increases 5%; Or the load in building heating and air conditioning reduces 5%	The thermal performance in building envelope increases 10%; Or the load in building heating and air conditioning reduces 10%	The thermal performance in building envelope increases 20% ; Or the load in building heating and air conditioning reduces 15%
The ratio of heat transfer coefficient of exterior windows of residential buildings in cold and severe cold regions reduced	5%	10%	20%
Water efficiency grade of sanitary appliances	Grade 3	Grade 2	
Sound insulation performance of residential building	-	The air-borne sound insulation performance between the outdoor and bedroom, and between the bedrooms on both sides of household partition wall (floor), and the impact sound insulation performance of the bedroom floor reach the average value of the base value and the comfort value	The airborne sound insulation performance between the outdoor and bedroom,and between the bedrooms on both sides of household partition wall (floor), and the impact sound insulation performance of the bedroom floor reach the comfort value
Reduction proportion of main indoor air pollutants	10%	20%	
Air permeability of external window			Comply with the requirements stipulated in the current relevant standards of the nation for building energy efficiency design, and the connection of the exterior window opening with the exterior window body shall be tight.

Notes:
1. The benchmark for improving the thermal performance of the building envelope and reducing the heat transfer coefficient of exterior windows of residential buildings in cold and severe cold regions are the requirements stipulated in the current relevant standards of the nation for building energy efficiency design.
2. The standard corresponding to sound insulation performance of residential buildings is the current national standard GB 50118 Code for design of sound insulation o f civil buildings.
3. The main indoor air pollutants include ammonia, formaldehyde, benzene, total volatile organic compounds, radon, inhalable particulate matter, etc. .
The benchmark for concentration reduction is the relevant requirements stipulated in the current national standard GB/T 18883 Indoor air quality standard.

Table 3.3: Technical Requirements of Star Green Buildings[6]

3.2.2 Assessment standard framework and content

The ASGB 2019 assessments consist of six assessments: Safety and Durability, Health and Comfort, Occupant Convenience, Resource Saving, and Environment Livability, Promotion and Innovation. There are a total of 110 assessment regulations, of which 40 are Prerequisite items and 12 are bonus items (promotion and innovation).

The Safety and Durability category puts forward the requirements of safety and durability for the building structure, construction site selection, building materials and building performance. There are 8 prerequisite items and 9 scoring items.

Health and Comfort category puts forward corresponding health and comfort requirements for the building's indoor exhaust system, indoor water supply and drainage system, and indoor lighting system. There are 9 prerequisite items and 11 scoring items.

Occupant Convenience category puts forward the corresponding living convenience requirements in the aspects of building travel, service facilities, intelligent operation and property management. There are 6 prerequisite items and 13 scoring items.

Resource Saving category puts forward corresponding requirements for the resource utilization of buildings and the use of green building materials. There are 10 prerequisite items and 18 scoring items.

Environmental Livability category makes requirements on the site ecology and landscape of the building as well as the outdoor physical environment. There are 7 prerequisite items and 9 scoring items.

There are 10 bonus items for Promotion and Innovation, which are for further promotion and innovation evaluation of buildings after meeting the above standards. Table 3.4 presents the ASGB 2019 Categories and Items.

Categories			Items
Safety and Durability	Prerequisite items		4.1.1 Site location
			4.1.2 Building structure and envelope requirements
			4.1.3 External facilities requirements
			4.1.4 Equipment connection requirements inside the building
			4.1.5 Exterior doors and windows requirements
			4.1.6 Waterproof and Moisture-proof design
			4.1.7 Passage spaces requirements of evacuation and rescue
			4.1.8 Safety signage system
	Scoring items	Safety	4.2.1 Seismic requirements
			4.2.2 Personnel safety protection measures
			4.2.3 Safety protection products or accessories
			4.2.4 Anti-slip measures
			4.2.5 Transportation system design
		Durability	4.2.6 Measures to improve the structural adaptability of building
			4.2.7 Measures to improve the durablility of building parts
			4.2.8 Improve the durability of building structure materials

Categories			Items
			4.2.9 Rationally use decorative building materials
Health and Comfort		Prerequisite items	5.1.1 Minimum requirements for pollutant concentration and non-smoking signs
			5.1.2 Measures to prevent the spread of indoor air pollution
			5.1.3 Water supply and drainage system requirements
			5.1.4 Minimum indoor noise level and sound insulation performance requirements
			5.1.5 Indoor lighting requirements
			5.1.6 Measures to ensure the Indoor thermal environment
			5.1.7 The thermal performance of the building envelope requirements
			5.1.8 Thermal environment adjustment device independently
			5.1.9 Carbon monoxide concentration monitoring device in underground garage
	Scoring items	Indoor Air Quality	5.2.1 Control the concentration of main indoor air pollutants
			5.2.2 Limit of harmful substances in-decoration materials

Categories			Items
		Water Quality	5.2.3 Water quality requirements
			5.2.4 Requirements for water storage facilities
			5.2.5 Marks requirement of water pipes, equipment and facilities
		Sound and Daylighting	5.2.6 Noise level requisment
			5.2.7 Sound insulation performance requirements
			5.2.8 Daylighting requirements
		Indooor Thermal Environment	5.2.9 Indoor thermal and humid environment requirements
			5.2.10 Natural ventilation effect requiements
			5.2.11 Adjustable shading facilities
Occupant Convenience	Prerequisite items		6.1.1 Accessible barrier-free walking system
			6.1.2 Public transportation station around the pedestrian entrance
			6.1.3 Parking lot settings and requirements
			6.1.4 Bicycle parking settings
			6.1.5 Building Equipment Management System requirements
			6.1.6 Information network system settings

Categories			Items
	Scoring items	Transit and Accessibility	6.2.1 Public transportation stations distance requirements
			6.2.2 Full-age design requirements
		Service Facility	6.2.3 Convenient public service
			6.2.4 Open space accessible by walking
			6.2.5 Fitness field and space setting
		Intelligent Operation	6.2.6 Energy measurement system and management system settings
			6.2.7 Air quality monitoring system settings
			6.2.8 Water metering system and water quality monitoring system
			6.2.9 Intelligent service system requirements
		Property Management	6.2.10 Energy and resources management system
			6.2.11 Average daily water consumption of building requirements
			6.2.12 Evaluation of operational effect of building regularly
			6.2.13 Green education publicity and practice mechanism
			7.1.1 Energy saving design requirements
			7.1.2 Measures to reduce the energy consyption

Categories			Items
			7.1.3 Temperature design requirements
			7.1.4 Energy saving in room lighting
			7.1.5 Sub-metering of energy consumption
			7.1.6 Elevator and escalator energy saving measures
			7.1.7 Water resource utilization plan
			7.1.8 Building structure requirements
			7.1.9 Architectural modeling elements requirements
			7.1.10 Building materials requirements
	Scoring items	Land Saving and Land Utilization	7.2.1 Economical and intensive use of land
			7.2.2 Underground Space Utilization
			7.2.3 Parking garage settings
		Energy saving and Energy Resources Utilization	7.2.4 Optimize the thermal performance of the building envelope
			7.2.5 Optimize the equipment's energy efficiency
			7.2.6 Reduce energy consumption of heating and air conditioning system
			7.2.7 Energy saving electrical equipment and control
			7.2.8 Reduce building energy consumption

Categories			Items
			7.2.9 Using renewable energy in accordance with regional conditions
			7.2.10 Sanitary apparatus requirements
			7.2.11 Water-saving equipment and technology
			7.2.12 Outdoor waterscape using rainwater facilities
			7.2.13 Use non-traditional water sources
		Material Saving and Green Materials	7.2.14 Integration design and construction of civil and decoration engineering
			7.2.15 Building structural materials and members requirements
			7.2.16 Building decoration selection
			7.2.17 Selection of recyclable, reusable and made-from-waste building materials
			7.2.18 Selection of green building materials
Environment Livability		Prerequisite items	8.1.1 Sunlight standards requirements
			8.1.2 Outdoor thermal environment requirements
			8.1.3 Green space allocation requirements
			8.1.4 Collection and discharge of rainwater

Categories			Items
			8.1.5 Signage system settings
			8.1.6 Pollution sources in the site
			8.1.7 Separation and collection of municipal solid waste
	Scoring items	Site Ecology and Landscape	8.2.1 Site ecological environmental
			8.2.2 Site rainwater management
			8.2.3 Green space settings
			8.2.4 Outdoor smoking area settings
			8.2.5 Green infrastructure for rainwater settings
		Outdoor Physical Environment	8.2.6 Reduce ambient noise
			8.2.7 Avoid light pollution
			8.2.8 Site wind environment requirements
			8.2.9 Reduce the heat island intensity
Promotion and Innovation	Bonus Items		9.2.1 Further reduce energy consumption for heating and air conditioning system
			9.2.2 Regional architectural style design
			9.2.3 Use of abandoned site and old building
			9.2.4 Green capacity rate
			9.2.5 Industriallized construction
			9.2.6 BIM Technology

Categories		Items
		9.2.7 Reduce carbon emission intensity analysing carbon emissions
		9.2.8 Green construction
		9.2.9 Inherent Defect Insurance of construction engineering quality
		9.2.10 Other innovation measures

Table 3.4: ASGB 2019 Categories and Items.(source: author's elaboration)

3.2.3 Analysis

The prerequisite items, scoring items and score values in ASGB 2019 were analyzed, the weighting and the average score of each item were calculated, and the different proportions of different categories were compared. The five basic categories of Safety and Durability, Health and Comfort, Occupant Convenience, Resource Conservation and Environmental Livability are analyzed, and the detailed data and integration are shown in Table 3.5, and further statistical analysis is shown in Figure 3.1 and Figure 3.2

	Required items	Credit items	Total items	Score	Average score	Weighting (%)
Safety and durability	8	9	17	180	10.6	18
Health and comfort	9	11	20	190	9.5	19
Occupant convenience	6	13	19	160	8.4	16
Resources saving	10	18	28	300	10.7	30
Environment livability	7	9	16	170	10.6	17
Total	40	60	100	1000	-	100
Note. Satisfying all prerequisites (40 in number) will award 400 points, so assume 10 points for each prerequisite.						

Table 3.5: Summary of ASGB 2019.(source: author's elaboration)

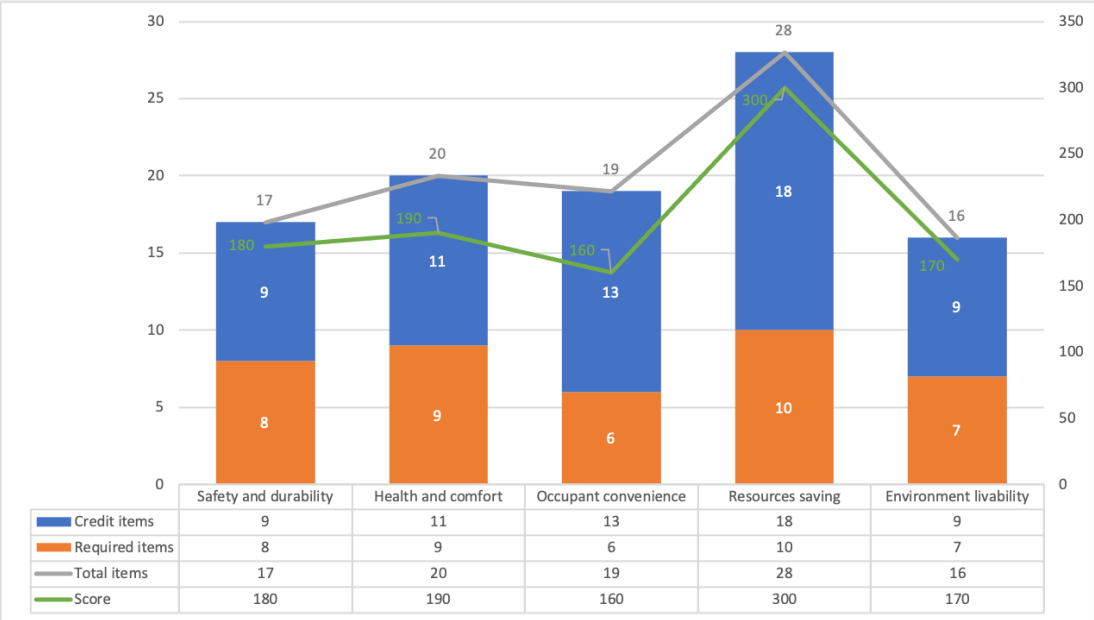


Figure 3.1: Summary analysis of ASGB 2019(a).(source: author's elaboration)

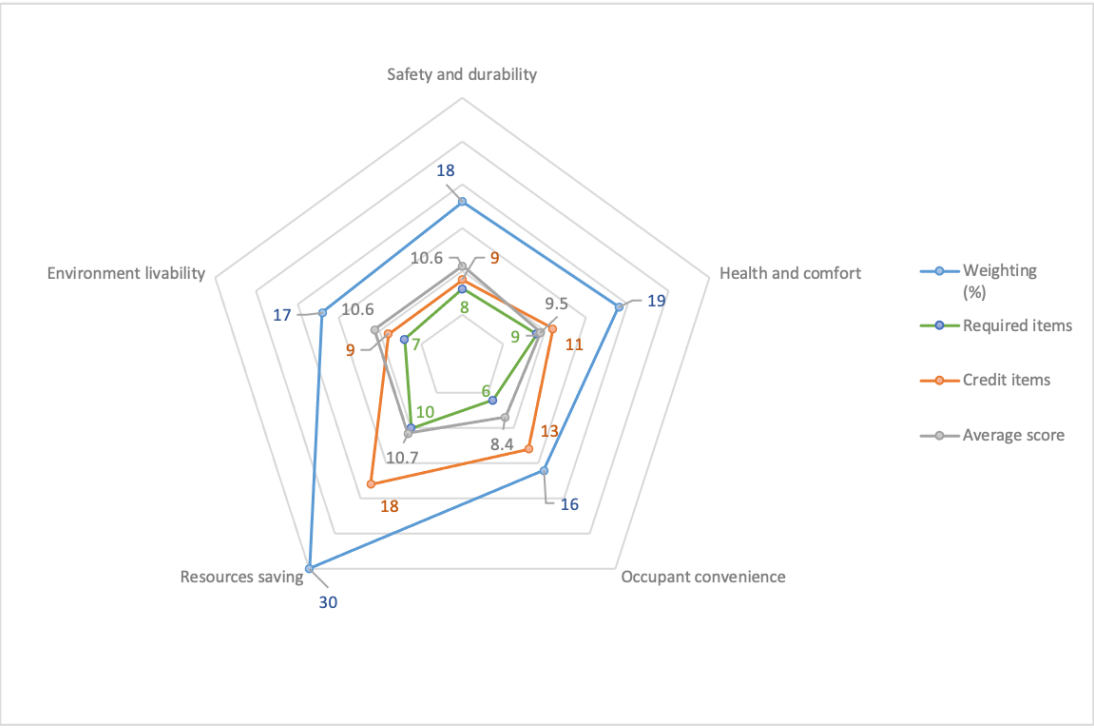


Figure 3.2: Summary analysis of ASGB 2019(b).(source: author's elaboration)

From the chart, it can be concluded that the most important item in the ASGB is Resource Saving, its number of prerequisite items and number of scoring items and weighting are in the first place. It shows the importance and comprehensive requirements for resources. The second is the emphasis on the Occupant Convenience category, although its weighting value is similar to the remaining items, it is more detailed in the number of scoring points, and the score requirements are higher in comparison. In addition, the remaining three data are slightly different, the Environmental Livability category is relatively weak, while the Health Comfort category is slightly stronger. It can be seen that the formulators of ASGB in China are not only paying attention to the shortage of resources, but also considering the convenience of people's lives. They start focusing on the experiences and feelings of the occupants, rather than focusing on performance

Chapter 4

ASGB 2014 vs 2019 (version comparison)

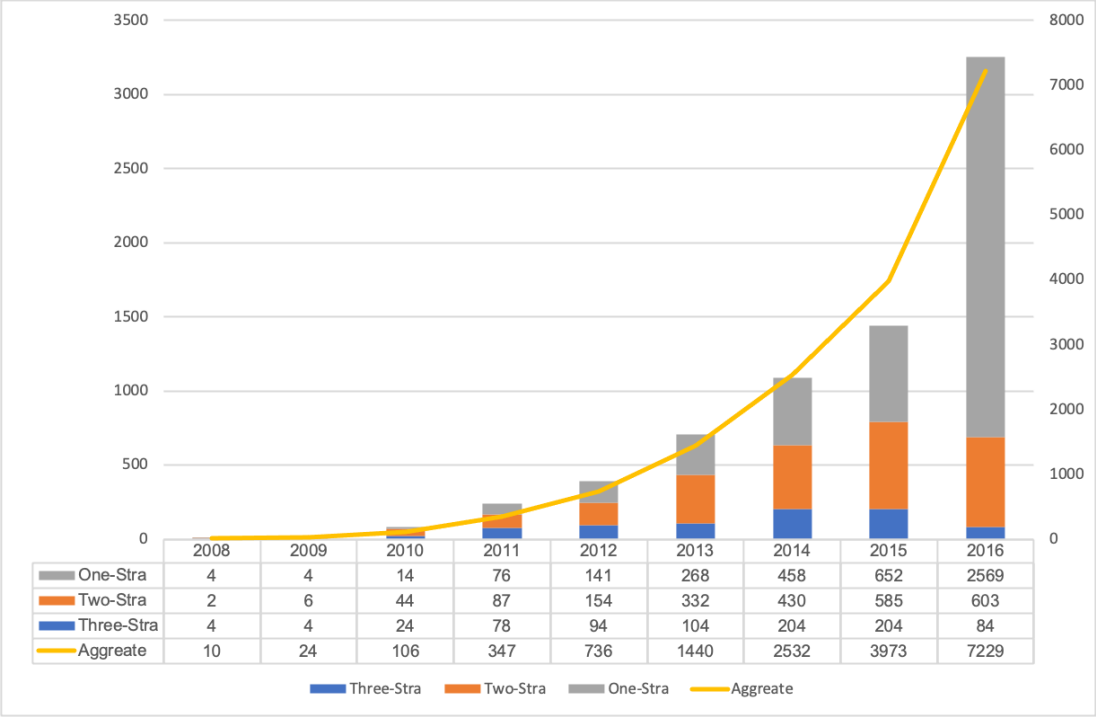
4.1 Overview

ASGB 2014 reflects some problems in the implementation process that cannot fully meet the requirements of the implementation of the green building assessment work:

1) Because this version assesses the design and operation separately and gives the label separately, many buildings focus on the design of the green building and only assess the design label, So much so that the real operational completion of green buildings cannot be achieved. As of 2017, the total building area of green buildings reached 1 billion m2, but the proportion of buildings with operational labels is very small. And in some places, the review of green building design construction drawings will gradually tilt the focus of green buildings to the design stage, and the proportion of green building operation labels will be further reduced;

2) This version focuses on the characteristics of the material and the energy saving part, mainly focusing on the green performance of the building itself and ignoring the convenience and comfort of the occupants in the living process, often making the user ignore the advantages of the green building in terms of health and comfort.

3) Green building technology has a new development in China (such as building industrialization, building information modelling, sponge city, etc.), which needs to be reflected and required in the standard.



	2008	2009	2010	2011	2012	2013	2014	2015	2016
One-Stra	4	4	14	76	141	268	458	652	2569
Two-Stra	2	6	44	87	154	332	430	585	603
Three-Stra	4	4	24	78	94	104	204	204	84
Aggreate	10	24	106	347	736	1440	2532	3973	7229

Figure 4.1: Percentage of ASGB Design Label and Operational Label, 2008-2018 [11]

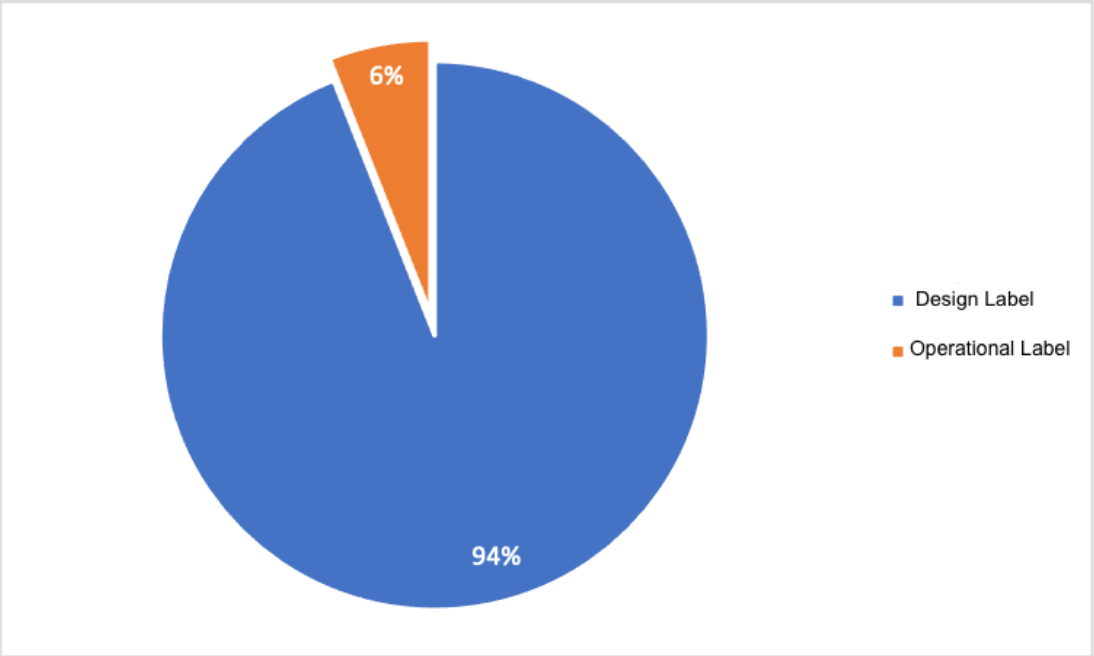


Figure 4.2: Statistics on the number of green building assessment labels from 2008-2016 [11]

Based on that, ASGB 2019 proposes four major changes to the above issues during the revision process:

1) Reconstruct the green building evaluation technical indicator system;

2) The design evaluation was cancelled and the evaluation time node of the green building was adjusted;

3) Set the basic level and increase the green building level;

4) There are higher standards for the specific evaluation content of green buildings, and the performance requirements of green buildings are improved.

The above four points are described in detail later in this section. And this section will also analyze and study the two versions (2014 and 2019), and verify whether the new version meets the new requirements through data analysis.

4.2 Changes of assessment technical indicators and evaluation time node

The assessment category of ASGB 2014 version mainly consists of 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, 7 major components. The content of the ASGB 2014 edition is mainly based on resource conservation and environmental protection, plus assessment categories for construction and operation management.

The ASGB 2019 edition splits the water-saving, land-saving, energy-saving, and material-saving parts of the old standard, and combines the conservation and utilization aspects of resources into the "Resource Conservation" section (as shown in Figure 4.3) in the building interior environment part, such as thermal environment, water quality, etc... The regulations on conservation and monitoring are integrated into the "Health and Comfort" category, forming a system of five assessment categories that emphasize the feeling of human habitation: Safety and Durability, Healthy and Comfortable, Occupant Convenience, Resource Conservation, and Environment Livability.

In terms of assessment methods, the original design assessment and operation assessment can be separated from the green building assessment to be carried out after the completion of the construction project, and the pre-assessment can be carried out after the completion of the design of the construction drawings of the construction project. The rating also changed the weight system of the 2014 edition and raised the score requirements for star green buildings. It is worth mentioning that ASGB 2019 puts forward higher and more requirements for the star rating of green buildings: One-star, Two-star, and Three-star buildings. in

addition to the required score of the building, it should be fully renovated and should meet a series of technical performance requirements.

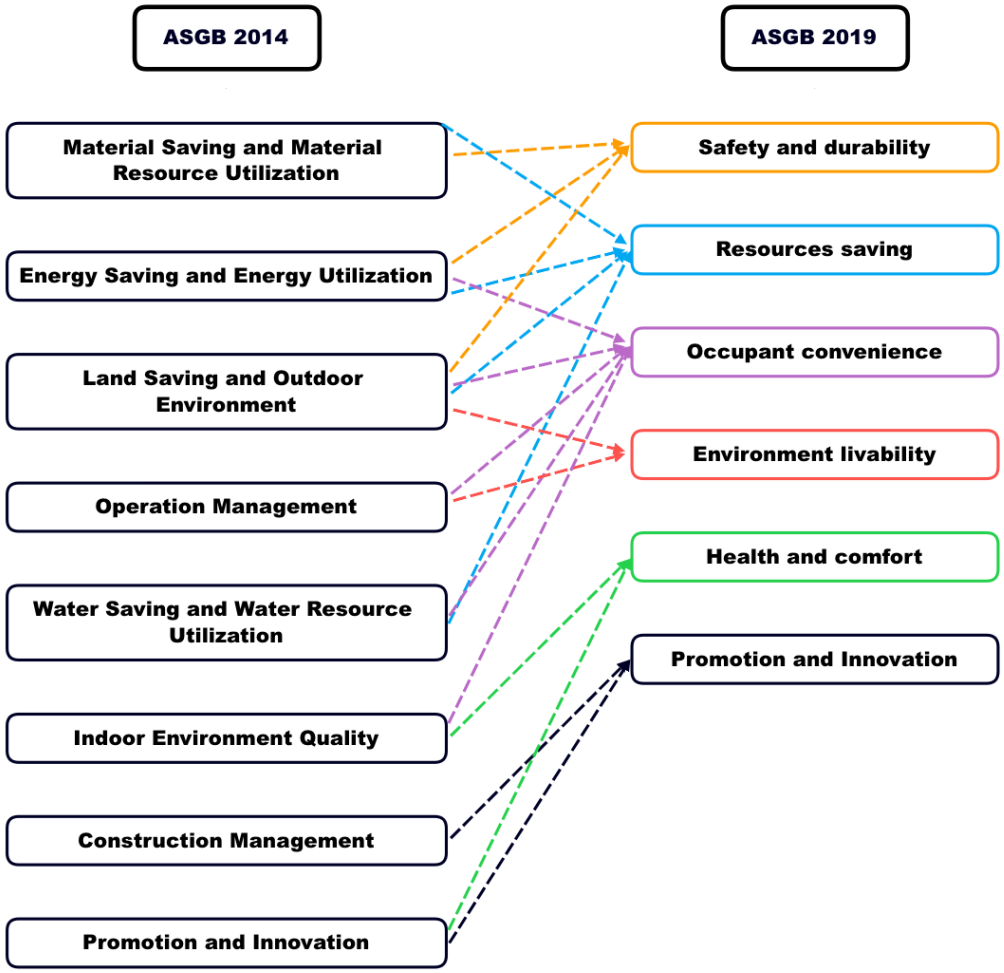


Figure 4.3: Comparison of rating systems for ASGB 2019 and AGBS 2014.(source: author's elaboration)

Building construction is divided into 4 stages: design stage, construction stage, completion stage, and operation stage, because the performance indicators of the building after completion are more certain, so most of the Assessment standard green buildings include the assessment of the completion stage. ASGB assesses

the design stage as well as the completion stage. However, due to a large number of projects that only assess design stage during the implementation of the standard, the actual effect after the completion is not confirmed. Therefore, the assessment of the design stage is cancelled in the ASGB 2019 edition, and only the pre-assessment is carried out in the design stage and the eligibility will be assessed only after the completion of the building.

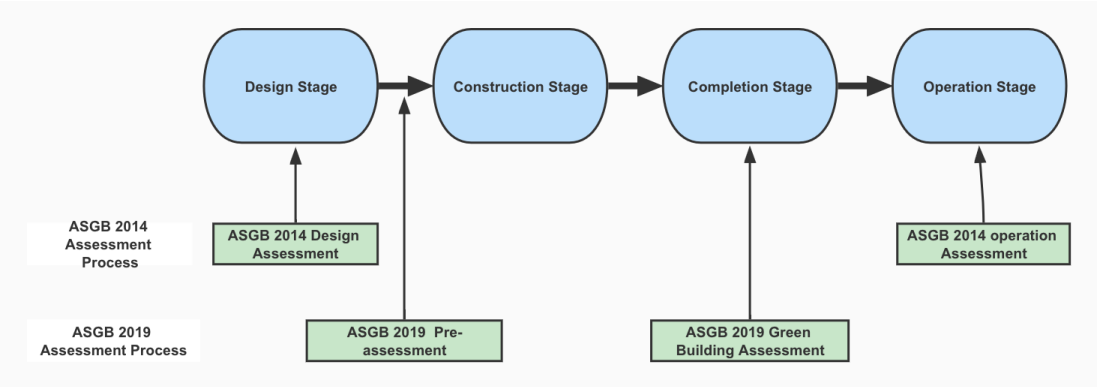


Figure 4.4: Changes of ASGB 2019 and 2014 assessment time node.(source: author's elaboration)

4.3 Changes in assessment levels and calculation methods

ASGB 2019 has made changes to the rating of green buildings. In the old assessment standard (ASGB 2014), it was classified as One-star, Two-star and Three-star, and the corresponding points should meet 50 points, 60 points and respectively 80 points. Although there is a minimum score of 40 points for each category, there is no rating for buildings that meet the requirements but do not reach the 1-star level. ASGB 2019 builds on the original One-star, Two-star and Three-star ratings, adding the concept of the basic level, that is, the assessment level when all control requirements are met but cannot reach the one-star require-

ment, and the scoring item for one-star, two-star and three-star are changed to 60, 70 and 85 points (see Table 4.1).

	ASGB 2014	ASGB 2019
Basic grade	-	$40 \leq \sum Q < 60$ (Meet all requirement items)
One-star grade	$50 \leq \sum Q < 60$	$60 \leq \sum Q < 70$
Two-star grade	$60 \leq \sum Q < 80$	$70 \leq \sum Q < 85$
Three-star grade	$80 \leq \sum Q$	$85 \leq \sum Q$

Table 4.1: ASGB 2019 vs. ASGB 2014 Rating Grade Changes[6,9]

There has also been some update in the calculation of scores (see Table 4.2). ASGB 2014 adopts the method of weighted summing, that is, the calculation method is the sum of the product of the score and the weight of each part of the scoring item, while in ASGB 2019 it is changed to the absolute score accumulation method, that is, the sum of the scores of each part and the sum of the points of the prerequisite items divided by 10 to get the final score.

	Calculation method	Note
ASGB 2014	$\sum Q = W_1Q_1 + W_2Q_2 + W_3Q_3 + W_4Q_4 + W_5Q_5 + W_6Q_6 + W_7Q_7 + Q_8$	$\sum$Q = The total score $W_1 \sim W_7$ = The weights of categories $Q_1 \sim Q_7$ = The scores of categories Q_8 = The score for Promotion and Innovation
ASGB 2019	$Q = (Q_0 + Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_A)/10$	Q = The total score Q_0 =The basic score of the prerequisite items, which is scored 400 points when all the prerequisite items are passed $Q_1 \sim Q_5$ =The scores of the scoring items of five categories Q_A = The score of bonus items for Promotion and Innovation

Table 4.2: The difference in how ASGB 2019 and ASGB 2014 are calculated[6,9]

This change makes a further detailed division of the classification of green building assessment process, and the buildings that are satisfied with the prerequisite items are classified as green buildings. The corresponding minimum grade is added to the green design concept in the building design process, which has a good role in promoting the green design concept and provides basic design expectations for building projects that do not meet the One-star level. The addition of the basic level expands the green building coverage.

At the same time, there may be such a problem: At present, some local standards in China have certain requirements for the number of green buildings in the project. Green buildings need to meet the One-star level before the emergence of the "Basic level". But after the "Basic level" appears, it is certified as a green building when it reaches the "Basic level". In the early stage of the practice of "Basic level", various regions may produce a large number of "Basic level" green buildings in order to meet the requirements of the number of green buildings. Although the new version of the assessment standards has been improved in various aspects, the new "Basic level" still does not meet the original One-star requirements. So the average energy-saving effect of green buildings that pass the evaluation in a short period of time may be reduced.

4.4 Analysis of the specific content of evaluation items

ASGB 2019 has made significant changes in evaluation items, as well as significant changes and additions in the content of specific items (as shown in Figures 4.5 and 4.6). In ASGB 2019, there are 59 items that have been modified based on the corresponding items of ASGB 2014. There are 39 items that are new and added item. Only 12 specific items continue to follow the ASGB 2014 item content.

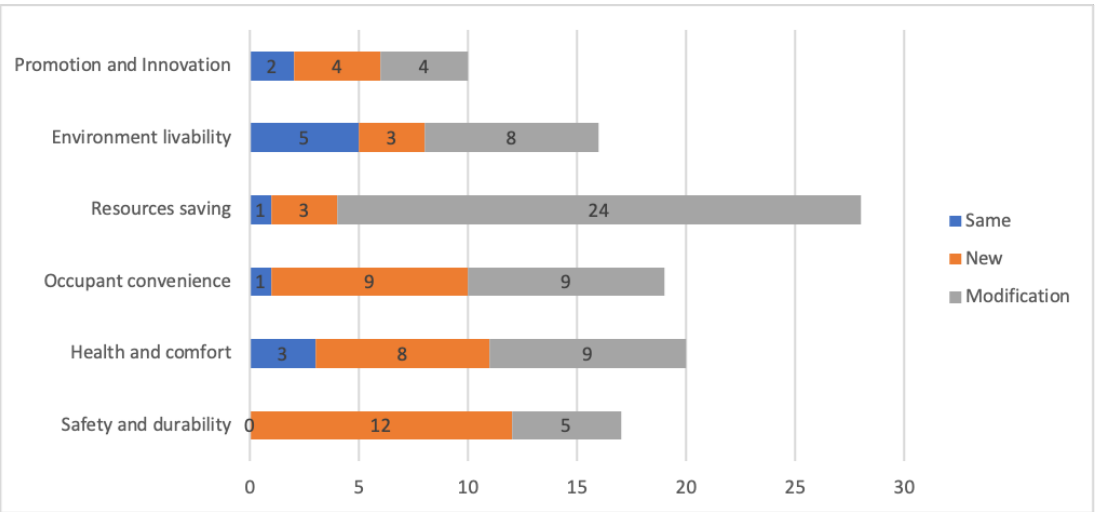


Figure 4.5: ASGB 2019 vs.ASGB 2014 Specific Item Consistency Comparison(a).(source: author's elaboration)

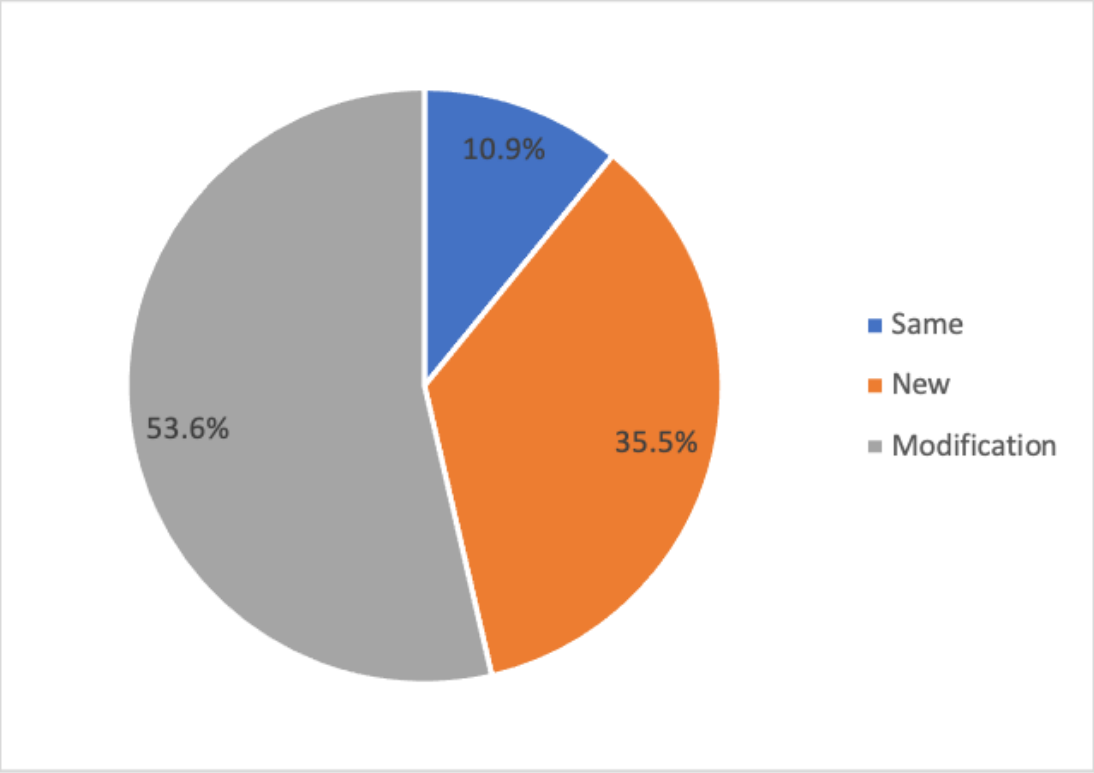


Figure 4.6: ASGB 2019 vs.ASGB 2014 Specific Item Consistency Comparison(b).(source: author's elaboration)

ASGB 2019 from the user's point of view, in order to make the living of the occupants be more healthy, comfortable and convenient, add a number of item: new safety category scoring items (see item 4.2.1, 4.2.2, 4.2.3, 4.2.4, 4.2.5); Requirements for water quality, clean water storage equipment, water appliances, labelling, etc. (see item 5.2.3, 5.2.4, 5.2.5); Acoustic environment, light environment and thermal comfort are valued to increase user satisfaction (see item 5.2.6, 5.2.7, 5.2.9, 5.2.11); Pay attention to ecological benefits, set up barrier-free systems in public areas, facilitate travel, reasonable parking space settings, and provide convenient public services (see item 6.1.1, 6.1.4, 6.2.2, 6.2.3, 6.2.5) and so on.

In addition to the new items, a number of items have become more detailed and improve the corresponding compliance requirements, and are evaluated from multiple perspectives and aspects: the relevant measures to improve the durability of the building system are specified in detail (see item 4.2.6, 4.2.7, 4.2.8, 4.2.9); Higher requirements are put forward for the use of energy-saving materials, energy-saving equipment and energy-saving facilities for life-cycle green energy-saving control (see item 5.2.2, 7.2.7, 7.2.10, 7.2.18, 8.2.5).

It can be said that the biggest change of ASGB 2019 compared to the 2014 version in specific items, in addition to the details and improvement of the requirements for green building performance, is around the concept of "people-oriented". Many new items have been added so that occupants can personally experience the advantages of green buildings. In this way, the concept of green buildings is further promoted.

This section will elaborate on and analyze the changes in the specific item of the old and new standards.

4.4.1 Safety and durability

The changes in ASGB 2019 are based on people's perception of buildings, and the building performance corresponding to the feelings of occupants is rearranged and classified. Building safety is the most basic attribute to be met when using a building, and the corresponding content is typeset as the top chapter in ASGB 2019. The safety and durability chapter has a total of 17 items (including 8 prerequisite items and 9 scoring items). Its main content can be divided into 3 main parts:

1) Site and site selection (site selection safety): try to avoid areas where geological disasters are likely to occur when selecting sites;

2) Building physical attributes (building structure and maintenance safety): including building durability, structural corresponding anti-shedding or anti-corrosion, etc.;

3) Reduce the possibility of danger in normal life (safety design in use): divert people and vehicles and keep evacuation corridors open.

The content of the "safety" part of the new edition mainly includes the following two parts: one is the "safety" of people when in use, that is, the "safety" of people is considered in the design and construction of buildings; The second is the "safety" of the building itself, that is, the safety considerations in terms of building materials, structure and design.
The details of this section are as follows:

1) The new content in "safety" has a total score of 53 points, from 4.2.1 to 4.2.5 covering five aspects: seismic resistance, safety protection, safety products, outdoor anti-slip measures and the organization and design of transportation, while "safety" is almost not covered in ASGB 2014;

2) As shown in Table 4.3, the new Safety and Durability category inherits the original entry mainly as the "Durability" section, which retains and retains part of ASGB 2014 Chapter 7 "Material Saving and Land Use" and the section of Chapter 6 "Water Conservation and Water Utilization". And the score has increased compared to ASGB 2014.

ASGB 2019				Changes compared to ASGB 2014
categories			Terms	
Safety and Durability	Prerequisite items		4.1.1 Site location	4.1.1 Modification
			4.1.2 Building structure and envelope requirements	New
			4.1.3 External facilities requirements	New
			4.1.4 Equipment connection requirements inside the building	New
			4.1.5 Exterior doors and windows requirements	New
			4.1.6 Waterproof and Moisture-proof design	New
			4.1.7 Passage spaces requirements of evacuation and rescue	New
			4.1.8 Safety signage system	New
	Scoring items	Safety	4.2.1 Seismic requirements	New
			4.2.2 Personnel safety protection measures	New
			4.2.3 Safety protection products or accessories	New
			4.2.4 Anti-slip measures	New
			4.2.5 Transportation system design	New
		Durability	4.2.6 Measures to improve the structural adaptability of building	7.2.4 Modification
			4.2.7 Measures to improve the durablility of building parts	6.2.2 Modification
			4.2.8 Improve the durability of building structure materials	7.2.11 Modification
			4.2.9 Rationally use decorative building materials	7.2.14 Modification

Table 4.3: Changes of safety and durability category.(source: author's elaboration)

In the "Safety and Durability" chapter, it contains requirements for the original safety aspects, such as the firmness of the structure or the durability of building components, as well as new requirements for geology and transportation. For example, 4.1.1 and 4.2.1 put forward suggestions and requirements for the site to avoid geological disasters and hazardous chemicals such as earthquakes; 4.1.2, 4.2.2, 4.2.3, 4.2.8 require and set the structure and maintenance structure of the building; Especially considering that children are more likely to be caught in the door and window, the second setting in 4.2.3 is that the use of doors and windows with anti-pinch function has a score of 5 points; 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.1.8, 4.2.6, 4.2.7, 4.2.9 mainly related to the use of safety and safety-related signs of building indoor equipment. Although scoring items only have 37 points in the chapter, including 5 prerequisite items, accounting for 62.5

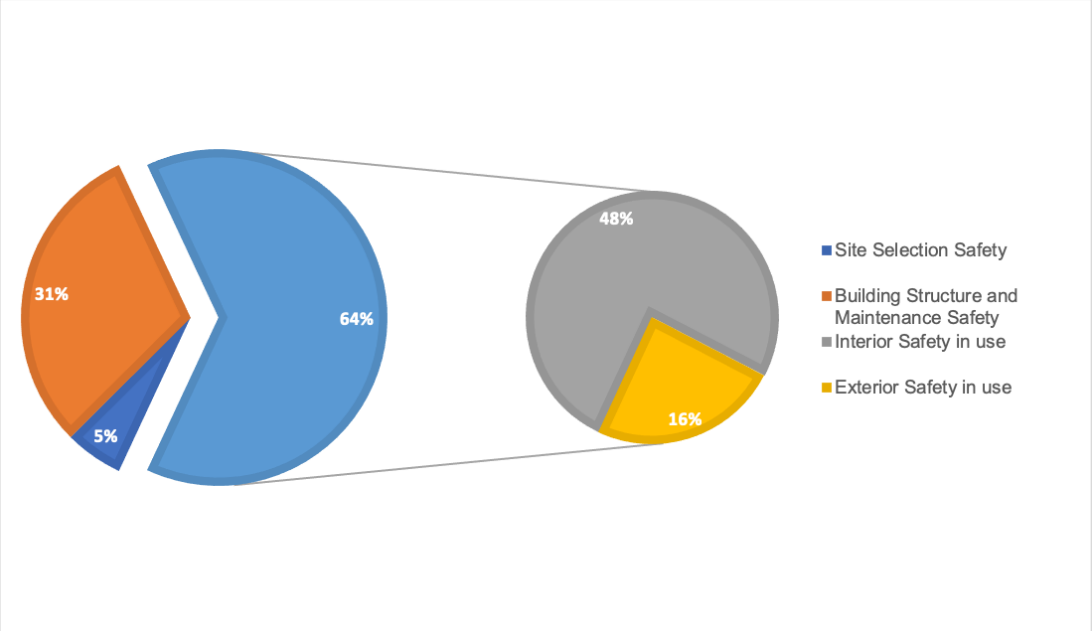


Figure 4.7: Proportion of points for each section of Safety and Durability (Note: treat each prerequisite item as 10 points).(source: author's elaboration)

In summary, the "Safety and Durability" chapter mainly involves the three

major parts of site selection safety, building structure and maintenance safety, and safety design in use, of which use safety can be divided into indoor use safety and outdoor use safety, that 2 Section. The score ratios for each section are shown in Figure 4.8. The proportion of building indoor safety content accounted for a relatively large part, followed by building structure and building maintenance, the high proportion of these two is due to the current domestic building is still dominated by high-rise, in the high-rise safety structure and indoor equipment is an important factor affecting the safety performance of the building.

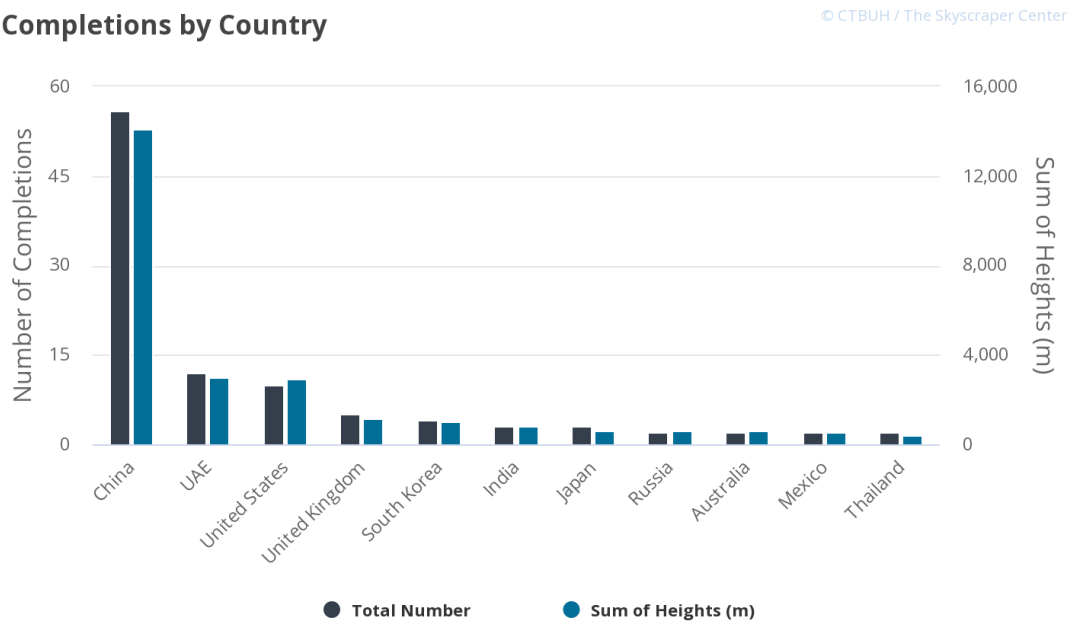


Figure 4.8: Global study of 200-meter-and-taller building completions for 2020[12]

4.4.2 Health and comfort

The "Health and Comfort" chapter has a total of 20 items (9 prerequisite items and 11 scoring items), which evaluates the health and comfort status of people in the building through five building physical environments: air quality, water quality, sound environment, light environment and thermal environment. These

five sections are also scored in detail (see Table 4.4).

ASGB 2019				Changes compared to ASGB 2014
categories			Terms	
Health and Comfort	Prerequisite items		5.1.1 Minimum requirements for pollutant concentration and non-smoking signs	8.1.7 Modification
			5.1.2 Measures to prevent the spread of indoor air pollution	8.2.11 Modification
			5.1.3 Water supply and drainage system requirements	New
			5.1.4 Minimum indoor noise level and sound insulation performance requirements	8.1.1/8.1.2 Idem
			5.1.5 Indoor lighting requirements	8.1.3 Modification
			5.1.6 Measures to ensure the Indoor thermal environment	8.1.4 Modification
			5.1.7 The thermal performance of the building envelope requirements	8.1.5/8.1.6 Modification
			5.1.8 Thermal environment adjustment device independently	New
			5.1.9 Carbon monoxide concentration monitoring device in underground garage	New
	Scoring items	Indoor Air Quality	5.2.1 Control the concentration of main indoor air pollutants	11.2.7 Modification
			5.2.2 Limit of harmful substances indecoration materials	New
		Water Quality	5.2.3 Water quality requirements	New
			5.2.4 Requirements for water storage facilities	New
			5.2.5 Marks requirement of water pipes, equipment and facilities	New
		Sound and Daylighting	5.2.6 Noise level requisment	8.2.1 Idem
			5.2.7 Sound insulation performance requirements	8.2.2 Idem
			5.2.8 Daylighting requirements	8.2.6/8.2.7 Modification
		Indooor Thermal Environment	5.2.9 Indoor thermal and humid environment requirements	New
			5.2.10 Natural ventilation effect requiements	8.2.10 Modification
			5.2.11 Adjustable shading facilities	8.2.8 Modification

Table 4.4: Changes of health and comfort category.(source: author's elaboration)

As shown in Table 4.4, most of the items in the Health and Comfort chapter of ASGB 2019 are from the Indoor Environmental Quality section of Chapter 8 of ASGB 2014. Because users spend most of their time indoors, the environment indoors is closely related to their health and comfort of them. Therefore, except for 5.1.3, the prerequisite items are inherited or adapted from the original indoor environmental quality entries. In addition to 5.2.1, the items used in the scoring items are also used or developed from the Indoor Environmental Quality chapter of ASGB 2014.

Most of the new items are concentrated in the water quality part. 4 of the water quality part are new items, including water quality transportation safety and measures related to water quality and water storage and sanitation. The remaining new items are 5.2.2 and 5.2.9, which are classified in the indoor air quality part and indoor thermal and humid environment Section. In addition to focusing on resource conservation and environmental protection, the new items pay more attention to the user's feelings and experiences when using sustainably.

At the same time, it optimizes and improves the requirements for lighting space and lighting efficiency, emphasizes the use of corresponding passive designs in different regions to meet the thermal comfort of the room and the effect of human health, and pays attention to the controllable design of heating, air conditioning and shading equipment. This chapter transitions more from mandatory design or specification to guiding people to save energy consumption according to their own needs under conditions that meet the comfort of the environment, infiltrating the concept of sustainability into people's daily lives.

The Health and Comfort chapter mainly deals with air quality, water quality, indoor humid and thermal environment, sound environment and light environment. From Figure 4.9, it can be seen that indoor thermal and humid environment and air quality account for a relatively large proportion, followed by the water

quality part score of 35 points.

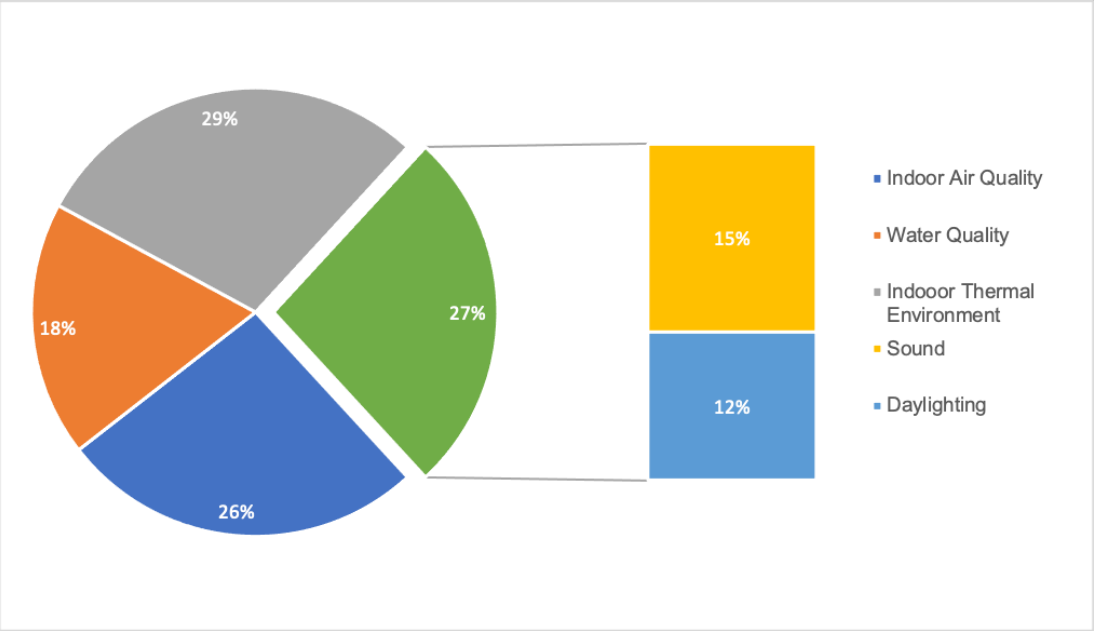


Figure 4.9: Proportion of points for each section of Health and Comfort.(source: author's elaboration)

4.4.3 Occupant Convenience

The chapter of " Occupant Convenience" mainly puts forward the requirements of green buildings from the aspects of travel, building peripheral service facilities, intelligent management and monitoring, which should meet the standards of the surrounding environment and daily life of users. There is a total of 19 items (6 prerequisite items, 13 scoring items).

Compared with the concentrated use of Health and Comfort in the previous chapter, the content of this chapter covers a richer scope, not only including items that can facilitate the user's life and work, but also including the survey and evaluation of satisfaction and resource consumption after the completion of the building (see Table 4.5 for details).

ASGB 2019				Changes compared to ASGB 2014
categories			Terms	
Occupant Convenience	Prerequisite items		6.1.1 Accessible barrier-free walking system	New
			6.1.2 Public transportation station around the pedestrian entrance	New
			6.1.3 Parking lot settings and requirements	New
			6.1.4 Bicycle parking settings	4.2.10 Idem
			6.1.5 Building Equipment Management System requirements	10.1.5 Modification
			6.1.6 Information network system settings	New
	Scoring items	Transit and Accessibility	6.2.1 Public transportation stations distance requirements	4.2.8 Modification
			6.2.2 Full-age design requirements	4.2.9 Modification
		Service Facility	6.2.3 Convenient public service	4.2.11 Modification
			6.2.4 Open space accessible by walking	New
			6.2.5 Fitness field and space setting	New
		Intelligent Operation	6.2.6 Energy measurement system and management system settings	5.1.3 Modification
			6.2.7 Air quality monitoring system settings	8.2.12 Modification
			6.2.8 Water metering system and water quality monitoring system	New
			6.2.9 Intelligent service system requirements	New
		Property Management	6.2.10 Energy and resources management system	10.2.2/10.2.3 Modification
			6.2.11 Average daily water consumption of building requirements	6.2.1 Modification
			6.2.12 Evaluation of operational effect of building regularly	New
			6.2.13 Green education publicity and practice mechanism	10.2.4 Modification

Table 4.5: Changes of Occupant convenience category.(source: author's elaboration)

Compared to ASGB 2014, ASGB 2 019 adds 6.2.12 and 6.2.13 to the evaluation of the later operational stage of the building, and also gradually begins to focus on the Post Occupancy Evaluation. It is one of the ways to slow down and improve the quality of the construction industry which is growing too fast. Produced in the 1960s, Post Occupancy Evaluation (POE) evaluates and organizes and feeds on aspects of the built environment, including user satisfaction evaluation and comprehensive performance evaluation. The development of post occupancy evaluation can not only determine the degree to which the building reaches the expected value after completion, but also feedback on the relevant data to the designer and the research party, which is conducive to the accumulation of data for secondary design or specification formulation.

Comprehensive analysis of this chapter, the Occupant Convenience chapter not only contains the travel in life, the use of surrounding service facilities, and the demand for activity venues/green spaces, but also contains intelligent monitoring management and evaluation of related content. The new "Occupant Convenience" section has further requirements for the data-based and intelligent management of green buildings, focusing more on guiding designers and users to pay attention to the experience of building users, providing convenient conditions for green travel such as public transportation and walking, and promoting the use of green building technology in real life.

4.4.4 Resources Saving

The chapter on Resource Saving is mainly divided into four parts: land saving and land use, energy conservation and energy utilization, water conservation and water utilization, and material saving and green building materials. There are 28 items in total (10 prerequisite items, 18 scoring items). However, there are only 3 new items, most of which are developed, extended and related to the first four

chapters of ASGB 2014 (see Table 4.6).

ASGB 2019				Changes compared to ASGB 2014
categories			Terms	
Resources Saving	Prerequisite items		7.1.1 Energy saving design requirements	5.2.1 Modification
			7.1.2 Measures to reduce the energy consyption	5.2.8 Modification
			7.1.3 Temperature design requirements	New
			7.1.4 Energy saving in room lighting	5.1.4 Modification
			7.1.5 Sub-metering of energy consumption	5.1.3 Idem
			7.1.6 Elevator and escalator energy saving measures	5.2.11 Modification
			7.1.7 Water resource utilization plan	6.2.4 Modification
			7.1.8 Building structure requirements	New
			7.1.9 Architectural modeling elements requirements	7.1.3 Modification
			7.1.10 Building materials requirements	7.2.7 Modification
	Scoring items	Land Saving and Land Utilization	7.2.1 Economical and intensive use of land	4.2.1 Modification
			7.2.2 Underground Space Utilization	4.2.3 Modification
			7.2.3 Parking garage settings	4.2.10 Modification
		Energy saving and Energy Resources Utilization	7.2.4 Optimize the thermal performance of the building envelope	5.2.3 Modification
			7.2.5 Optimize the equipment's energy efficiency	5.2.4/11.2.2 Modification
			7.2.6 Reduce energy consumption of heating and air conditioning system	5.2.5 Modification
			7.2.7 Energy saving electrical equipment and control	5.2.6 Modification
			7.2.8 Reduce building energy consumption	5.2.16 Modification
			7.2.9 Using renewable energy in accordance with regional conditions	5.2.16 Modification
			7.2.10 Sanitary apparatus requirements	5.2.6/11.2.4 Modification
			7.2.11 Water-saving equipment and technology	6.2.7/6.2.8 Modification
			7.2.12 Outdoor waterscape using rainwater facilities	6.2.12 Modification
			7.2.13 Use non-traditional water sources	6.2.10/6.2.11 Modification
		Material Saving and Green Materials	7.2.14 Integration design and construction of civil and decoration engineering	7.2.3/9.2.12 Modification
			7.2.15 Building structural materials and members requirements	7.2.10 Modification
			7.2.16 Building decoration selection	7.2.6 Modification
			7.2.17 Selection of recyclable, reusable and made-from-waste building materials	7.2.12/7.2.13 Modification
			7.2.18 Selection of green building materials	New

Table 4.6: Changes of Resources saving category.(source: author's elaboration)

From the classification of prerequisite items, most of the revised items are scoring item content in ASGB 2014. The change from the original scoring item to the prerequisite item that needs to be enforced, indicates that the technical level and standard of the building in terms of energy conservation and utilization have been greatly improved compared with the 2014 version.

Standards for water conservation and water use incorporate much of what is in ASGB 2014. However, compared to the proportion, the partial score of this chapter in ASGB 2019 has decreased for two main reasons:

1) The corresponding technologies and requirements for water conservation have been improved. For example, the bonus points in 7.2.10 that involve hygienic appliances reaching water efficiency level 1 were originally included in the "Promotion and Innovation" category of ASGB 2014, which explains that the requirements were more stringent or difficult to achieve when ASGB 2014 was formulated. But in ASGB 2019, the same items have been summarized in the previous chapters as one of the standards for water saving, and the corresponding technical requirements and standards have been improved.

2) Some of the measures and contents of water conservation are assigned to other chapters. The use of water resources involves a wide range, not only in the use of water-saving equipment and more effective irrigation need to consider the conservation of water resources, but also in daily life and the use of fire fighting facilities also need to consider the safety. So in ASGB 2019 "water" part are divided in more detail, and water safety related content is scattered into other chapters.

4.4.5 Environment livability

The content of "Environmental Livability" mostly involves the outdoor environment, and the combination with the indoor environment in "Health and Comfort" standardizes advocates for the indoor and outdoor environment of the building Among them. There are 7 prerequisite items and 9 scoring items, a total of 16 items.

As shown in Table 4.7, comparing ASGB 2014 with ASGB 2019, it can be seen that most of the items in ASGB 2019 are more stringent and the scoring item are more detailed than in the previous version.

8.1.5 and 8.2.4 are new items that emphasize the identification system inside and outside the building and in smoking areas, respectively, and gradually emphasize the role of "signage" in reasonably guiding the user's activities.

ASGB 2019				Changes compared to ASGB 2014
categories			Terms	
Environment Livability	Prerequisite items		8.1.1 Sunlight standards requirements	4.1.4 Idem
			8.1.2 Outdoor thermal environment requirements	New
			8.1.3 Green space allocation requirements	5.2.15 Idem
			8.1.4 Collection and discharge of rainwater	4.2.13 Modification
			8.1.5 Signage system settings	New
			8.1.6 Pollution sources in the site	4.1.3 Idem
			8.1.7 Separation and collection of municipal solid waste	10.1.2 Modification
	Scoring items	Site Ecology and Landscape	8.2.1 Site ecological environmental	4.2.12 Idem
			8.2.2 Site rainwater management	4.2.14 Modification
			8.2.3 Green space settings	4.2.2 Modification
			8.2.4 Outdoor smoking area settings	New
			8.2.5 Green infrastructure for rainwater settings	4.2.13 Modification
		Outdoor Physical Environment	8.2.6 Reduce ambient noise	4.2.5 Modification
			8.2.7 Avoid light pollution	4.2.4 Modification
			8.2.8 Site wind environment requirements	4.2. Idem
			8.2.9 Reduce the heat island intensity	4.2.7 Modification

Table 4.7: Changes of Environment livability category.(source: author's elaboration)

4.4.6 Promotion and Innovation

The total score of the Promotion and Innovation category contains 2 prerequisite items and 10 bonus items that are 180 points, of which 9.2.1, 9.2.2, 9.2.4, and 9.2.9 are new items, and the remaining items are used and modified.

ASGB 2019			Changes compared to ASGB 2014
categories		Terms	
Promotion and Innovation	Bonus Items	9.2.1 Further reduce energy consumption for heating and air conditioning system	New
		9.2.2 Regional architectural style design	New
		9.2.3 Use of abandoned site and old building	11.2.9 Idem
		9.2.4 Green capacity rate	New
		9.2.5 Industriallized construction	7.2.5 Modification
		9.2.6 BIM Technology	11.2.10 Modification
		9.2.7 Reduce carbon emission intensity analysing carbon emissions	11.2.11 Idem
		9.2.8 Green construction	9.2.6/9.2.7 Modification
		9.2.9 Inherent Defect Insurance of construction engineering quality	New
		9.2.10 Other innovation measures	11.2.12 Modification

Table 4.8: Changes of Promotion and Innovation category.(source: author's elaboration)

There are new differences in the new item in the following respects:

- Energy:9.2.1 Add bonus points to further reduce energy consumption on the basis of 7.1.2, 7.2.5 and 7.2.6;
- Cultural inheritance:9.2.2 proposes to have extra points for buildings with suitable regional characteristics.Proposes the inheritance of architectural culture in green buildings are exploration and progress of the social aspects of the sustainable three parts of "environment, society and economy"in ASGB 2019.

Chapter 5

Comparison of ASGB and LEED standards

5.1 Overview of comparisons

The standard for comparison are LEED v4 1 BD+C (New Construction) and ASGB 2019 (GB/T 50378-2019).

The ASGB 2019 pays more attention to the details of the building, which is more trivial. Although it is divided into categories before entering the scoring items, in terms of the sensory of the scoring items, it is still unsystematic and somewhat messy. In terms of individual scoring items, there is a lack of follow-up content for some items, such as the basis for judging the score, the quantitative qualification of the achievement of the requirements, and the architectural feedback on the testing data, which is somewhat formal and could significantly reduce the actual green effect of the building. However, after the ASGB 2019 update, many requirements for the humanization of users and building use have been added. In addition to focusing on the evaluation of the building itself, some humanistic care has been added.

LEED building regulations have been largely taken into account by the ASGB. Its standard assessment is simple and efficient. The formulation of the LEED item itself is forward-looking and thoughtful, not only considering the greening of the building itself, but also tracing the source, limiting the non-green behaviour from the source, and the impact and strength of the item are wide, reflecting the depth and vision of the formulator.

5.2 Comparison of LEED and China's green building rating systems

LEED in the United States developed into the latest version of LEED v4.1 in 2018, and the system has developed so far, covering almost all building types and different stages of buildings, including new construction, interior, operation and maintenance, and core and shell. LEED v4.1 divides the rating system into four groups, each of which includes various building types, as detailed in Table 5.1. Among them, Building Design and Construction (BD+C) is the most widely used, and it is also the classification of the earliest version of LEED-NC1.0. It is used in new construction or major renovation buildings, including 8 types of building standards, including new construction, core and shell, schools, retail, healthcare, data centers, hospitality, and warehousing and distribution centers.

In terms of the assessment stage of China's green building rating system, in addition to the "Assessment standard for green building" GB/T 50378-2019, there are also the "Assessment standard for green retrofitting of existing building" for the renovation of existing buildings; "Assessment standard for green eco-district" for urban areas. It is also constantly improving for various types of buildings: "Evaluation Standard for green office building", "Assessment Standard for green store building", "Assessment Standard for green hospital building" etc.., a total of

LEED v4.1 Rating System Groups	LEED v4.1 Rating System
LEED v4.1 Building Design +Construction	LEED v4.1 BD+C: New Construction
	LEED v4.1 BD+C: Core and Shell
	LEED v4.1 BD+C: Schools
	LEED v4.1 BD+C: Retail
	LEED v4.1 BD+C: Data Centers
	LEED v4.1 BD+C: Waewhouse and Distribution Centers
	LEED v4.1 BD+C: Hospitaloty
	LEED v4.1 BD+C: Healthcare
LEED v4.1 Residential	LEED v4.1 Residential BD+C: Single Family Homes
	LEED v4.1 Residential BD+C: Multifamily Homes
	LEED v4.1 Residential BD+C: Multifamily Homes Core and Shell
LEED v4.1 Interior Design + Construction	LEED v4.1 IN+C: commercial interiors
	LEED v4.1 IN+C: Retail
	LEED v4.1 IN+C: Hospitalily
LEED v4.1 Operations + Maintenance	LEED v4.1 O+M: Existing BuIlding
	LEED v4.1 O+M: Existing Interiors
LEED v4.1 Cities and Communities	LEED v4.1 Cities and Communities: Plan and Design
	LEED v4.1 Cities and Communities: Existing

Table 5.1: LEED v4.1 Rating System[7]

9 special assessment standards for various types of buildings; In terms of region, all provinces in the country have basically formulated and promulgated local standards on the basis of national standards.

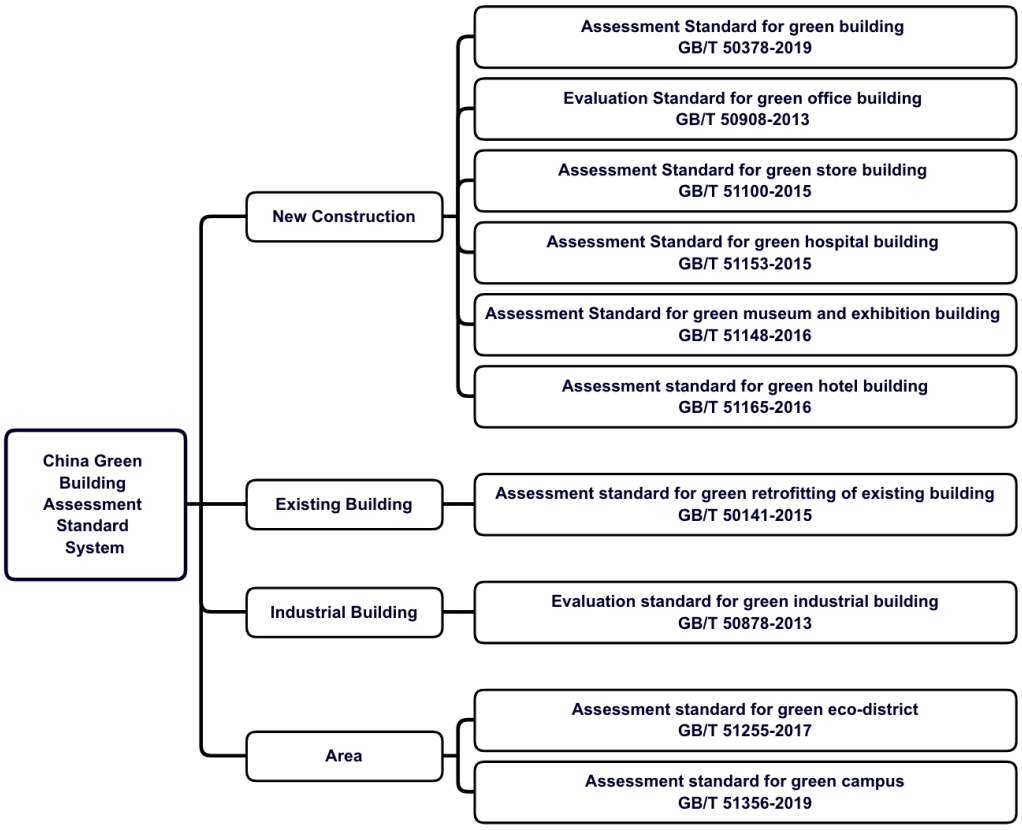


Figure 5.1: China's green building rating system.(source: author's elaboration)

In general, LEED's green building rating system has covered almost all building types and building stages, but China's green building rating system is not comprehensive enough compared with LEED. Moreover, from the perspective of ASGB 2019 alone, it only targets public buildings and residential buildings, and there is no more detailed distinction or coverage of different stages of building objects.

5.3 Basic comparison

LEED v4.1BD+C (NC) and ASGB 2019 standards were selected for specific comparison.

	LEED v4.1	ASGB 2019
country	USA	China
When the original version was issued	1998	2006
The latest version was issued	2018	2019
Issuing agency	USGBC (The U.S.Green Building Council)	MOHURD (Ministry of Housing and Urban Rural Development, PRC)
Nature of participation	Voluntary + mandatory	Voluntary + mandatory
Standard definitions	The world's most popular and widely used green building assessment standard.	China's most authoritative green building assessment standard
Means of promotion	Policy Mandatory Tax Exemption Building Density Incentive Tax Refund Policy Expedited Approval Reduce Approval Fees Refund Assessment Fees	Policy Mandatory Leadership Assessment Content Award Threshold Bonus Low-interest Loan Tax Preferential Consumer Home Purchase Loan Preferential Land Transfer Incentive Floor Area Ratio Reward Building Area Reward Approval Priority Qualification plus points
Evaluate the object	New Construction Core and Shell Data Centers Healthcare Hospitality Retail Schools Warehouse and Distribution Centers	Residential buildings Public buildings
Specific comparison criteria	LEED v4.1 BC+D(NC)	ASGB 2019
Number of terms	56	112
Weight hierarchy	Level 1	Level 1
Rating calculation method	$\sum$(Categories Score)	$Q = (Q_0 + Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_A)/10$
Assessment section	Integrative Process Location and Transportation Sustainable Sites Water Efficiency Energy and Atmosphere Materials and Resources Indoor Environmental Quality Innovation Regional Priority	Safety and Durability Health and Comfort Occupant Convenience Resources Saving Environment Livability Promotion and Innovation
Grade indicator	Score	Score
Presentation of results	Building Rating	Building Rating
Certification level	Level 4	Level 4
Certification results	Platinum Gold Silver certified	One star Two star Three star Basic
Review certification	Qualified persons who have passed an official examination of the institution	Ministry of Housing and Urban Rural Development

Table 5.2: Basic comparison of standards[6,7]

5.4 Comparison of evaluation items

LEED v4.1 BD+C(NC) and ASGB 2019 were selected for detailed comparison.

5.4.1 Classification method

There are differences between the standards in their own formulation logic. Therefore, to facilitate comparison, all the standard sections were broken up and all the evaluation items were reclassified in the same way.

All definitions of Green Buildings generally agree on three themes: 1. Efficient use of resources; 2. Creating a healthy and comfortable living environment; 3. Living in harmony with the surrounding environment. The 8 sections in the central column of figure 5.2 are the essential factors to realize the themes above. For example, the section “Management”, “Water”, “Energy” and “Material and design” are relative to theme 1; The section “Management”, “Location”, “Indoor Environmental” and “Transportation”are relative to theme 2; While the section “Outdoor Environmental” and “Management” are relative to theme 3. In another word, the 8 items embody those 3 themes of Green Building.

Therefore, the two standard items are reclassified into these 8 sections based on their specific contents. For example, the items in the category “Location and Transport” in LEED are divided into two sections: “Transport” and “Location”. Details are shown in Figure 5.2. The two standard items of the new section are then integrated and compared.

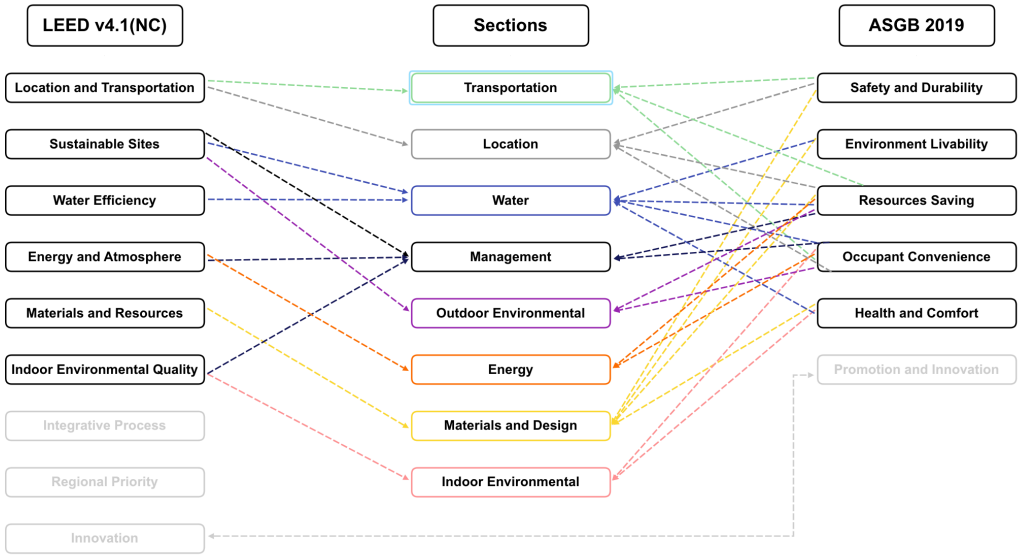


Figure 5.2: Comparison and classification of ASGB2018 and LEED in item.(source: author's elaboration)

For comparison, the sector classification will not discuss the bonus items "Promotion and Innovation" in ASGB 2019, "Regional Priority", "Integrative Process" and "Innovation" in LEED v4.1, which will be discussed in a later section.

The new sections are divided into 8 sections: Materials and Design, Energy, Water, Transportation, Indoor Environmental, Outdoor Environmental, Location, and Management.

Section	Explaination
Management	Management includes various stages (design, construction, operation, etc.) and overall management: planning management of pre-design (e.g. Site Assessment), planning management in the design process (e.g. Grid Harmonization), construction plan management (e.g. Construction Indoor Air Quality Management Plan), commissioning and testing before delivery (e.g. Indoor Air Quality Assessment),Monitoring and after-sales management in operation (e.g. Evaluation of operational effect of building regularly), and overall management (e.g. Integration design).
Materials and Design	Materials and design include aspects of the source and Ingredient of building materials(e.g. Sourcing of Raw Materials, Material Ingredients), as well as design structure and safety(e.g. Seismic requirements, Anti-slip measures).
Energy	Energy includes measures to achieve energy saving, equipment and design(e.g. Optimize Energy Performance, Enhanced Refrigerant Management).
Water	Water includes measures to achieve water conservation, equipment and water requirements(e.g. Indoor Water Use Reduction, Rainwater Management, Water quality requirements).
Transportation	Transportation includes traffic access(e.g. Reduced Parking Footprint) and travel aspects(e.g. Access to Quality Transit).
Indoor Environmental	Including indoor sound(e.g. Acoustic Performance), light(e.g. Interior Lighting), air(e.g. Enhanced Indoor Air Quality Strategies), thermal and humid environment(e.g. Thermal Comfort) and other aspects(e.g. Quality Views).
Outdoor Environmental	Including outdoor site planning(e.g. Open Space), outdoor light(e.g. Light Pollution Reduction), thermal and humid environment(e.g. Heat Island Reduction), etc.
Location	Including various requirements for site selection(e.g. Surrounding Density and Diverse Uses, Sensitive Land Protection).

Table 5.3: Explaination of the new section.(source: author's elaboration)

The following table shows the items reclassification of ASGB and LEED, and the statistical analysis of the distribution of the two standards in the new

category section. Table 5.4 and Table 5.5 show the items of ASGB and LEED that are specifically included in New sections, with different colours representing different New sections (Location, Materials and Design, Transport, Indoor Environmental, Water, Management, Outdoor Environmental, Energy).

Categories	Items
Location and Trasportation (LT)	LEED for Neighborhood Development Location
	Sensitive Land Protection
	High Priority Site and Equitable Development
	Surrounding Density and Diverse Uses
	Access to Quality Transit
	Bicycle Facilities
	Reduced Parking Footprint
	Electric Vehicles
Sustainable Sites (SS)	Construction Activity Pollution Prevention
	Site Assessment
	Protect or Restore Habitat
	Open Space
	Rainwater Management
	Heat Island Reduction
	Light Pollution Reduction
Water Efficiency (WE)	**Outdoor Water Use Reduction**
	Indoor Water Use Reduction
	Building-Level Water Metering
	Outdoor Water Use Reduction
	Indoor Water Use Reduction
	Optimize Process Water Use
	Water Metering
Energy and Atmosphere (EA)	Fundamental Commissioning and Verification
	Minimum Energy Performance
	Building-Level Energy Metering
	Fundamental Refrigerant Management
	Enhanced Commissioning
	Optimize Energy Performance
	Advanced Energy Metering
	Grid Harmonization
	Renewable Energy
	Enhanced Refrigerant Management
Materials and Resources (MR)	Storage and Collection of Recyclables
	Building Life-Cycle Impact Reduction
	Building Ptoduct Disclosure and Optimization - Environmental Product Declarations(EPD)
	Building Ptoduct Disclosure and Optimization - Sourcing of Raw Materials
	Building Ptoduct Disclosure and Optimization - Material Ingredients
	Construction and Demolition Waste Management
Indoor Environmental Quality (EQ)	Minimum Indoor Air Quality Performance
	Environmental Tobacco Smoke Control
	Enhanced Indoor Air Quality Strategies
	Low-Emitting Materials
	Construction Indoor Air Quality Management Plan
	Indoor Air Quality Assessment
	Thermal Comfort
	Interior Lighting
	Daylight
	Quality Views
	Acoustic Performance

Table 5.4: Items of LEED reclassfication.(source: author's elaboration)

Categories	Items
Safety and Durability	4.1.1 Site location
	4.1.2 Building structure and envelope requirements
	4.1.3 External facilities requirements
	4.1.4 Equipment connection requirements inside the building
	4.1.5 Exterior doors and windows requirements
	4.1.6 Waterproof and Moisture-proof design
	4.1.7 Passage spaces requirements of evacuation and rescue
	4.1.8 Safety signage system
	4.2.1 Seismic requirements
	4.2.2 Personnel safety protection measures
	4.2.3 Safety protection products or accessories
	4.2.4 Anti-slip measures
	4.2.5 Transportation system design
	4.2.6 Measures to improve the structural adaptability of building
	4.2.7 Measures to improve the durablility of building parts
	4.2.8 Improve the durability of building structure materials
	4.2.9 Rationally use decorative building materials
Health and Comfort	5.1.1 Minimum requirements for pollutant concentration and non-smoking signs
	5.1.2 Measures to prevent the spread of indoor air pollution
	5.1.3 Water supply and drainage system requirements
	5.1.4 Minimum indoor noise level and sound insulation performance requirements
	5.1.5 Indoor lighting requirements
	5.1.6 Measures to ensure the Indoor thermal environment
	5.1.7 The thermal performance of the building envelope requirements
	5.1.8 Thermal environment adjustment device independently
	5.1.9 Carbon monoxide concentration monitoring device in underground garage
	5.2.1 Control the concentration of main indoor air pollutants
	5.2.2 Limit of harmful substances indecoration materials
	5.2.3 Water quality requirements
	5.2.4 Requirements for water storage facilities
	5.2.5 Marks requirement of water pipes, equipment and facilities
	5.2.6 Noise level requisment
	5.2.7 Sound insulation performance requirements
	5.2.8 Daylighting requirements
	5.2.9 Indoor thermal and humid environment requirements
	5.2.10 Natural ventilation effect requiements
	5.2.11 Adjustable shading facilities
Occupant Convenience	6.1.1 Accessible barrier-free walking system
	6.1.2 Public transportation station around the pedestrian entrance
	6.1.3 Parking lot settings and requirements
	6.1.4 Bicycle parking settings
	6.1.5 Building Equipment Management System requirements
	6.1.6 Information network system settings
	6.2.1 Public transportation stations distance requirements
	6.2.2 Full-age design requirements
	6.2.3 Convenient public service
	6.2.4 Open space accessible by walking
	6.2.5 Fitness field and space setting
	6.2.6 Energy measurement system and management system settings
	6.2.7 Air quality monitoring system settings
	6.2.8 Water metering system and water quality monitoring system
	6.2.9 Intelligent service system requirements
	6.2.10 Energy and resources management system
	6.2.11 Average daily water consumption of building requirements
	6.2.12 Evaluation of operational effect of building regularly
	6.2.13 Green education publicity and practice mechanism
Resources Saving	7.1.1 Energy saving design requirements
	7.1.2 Measures to reduce the energy consyption
	7.1.3 Temperature design requirements
	7.1.4 Energy saving in room lighting
	7.1.5 Sub-metering of energy consumption
	7.1.6 Elevator and escalator energy saving measures
	7.1.7 Water resource utilization plan
	7.1.8 Building structure requirements
	7.1.9 Architectural modeling elements requirements
	7.1.10 Building materials requirements
	7.2.1 Economical and intensive use of land
	7.2.2 Underground Space Utilization
	7.2.3 Parking garage settings
	7.2.4 Optimize the thermal performance of the building envelope
	7.2.5 Optimize the equipment's energy efficiency
	7.2.6 Reduce energy consumption of heating and air conditioning system
	7.2.7 Energy saving electrical equipment and control
	7.2.8 Reduce building energy consumption
	7.2.9 Using renewable energy in accordance with regional conditions
	7.2.10 Sanitary apparatus requirements
	7.2.11 Water-saving equipment and technology
	7.2.12 Outdoor waterscape using rainwater facilities
	7.2.13 Use non-traditional water sources
	7.2.14 Integration design and construction of civil and decoration engineering
	7.2.15 Building structural materials and members requirements
	7.2.16 Building decoration selection
	7.2.17 Selection of recyclable, reusable and made-from-waste building materials
	7.2.18 Selection of green building materials
Environment Livability	8.1.1 Sunlight standards requirements
	8.1.2 Outdoor thermal environment requirements
	8.1.3 Green space allocation requirements
	8.1.4 Collection and discharge of rainwater
	8.1.5 Signage system settings
	8.1.6 Pollution sources in the site
	8.1.7 Separation and collection of municipal solid waste
	8.2.1 Site ecological environmental
	8.2.2 Site rainwater management
	8.2.3 Green space settings
	8.2.4 Outdoor smoking area settings
	8.2.5 Green infrastructure for rainwater settings
	8.2.6 Reduce ambient noise
	8.2.7 Avoid light pollution
	8.2.8 Site wind environment requirements
	8.2.9 Reduce the heat island intensity
Note: Location——, Materials and Design——, Transport——, Indoor Environmental——, Water——, Management——, Outdoor Environmental——, Energy——	

Table 5.5: Items of ASGB reclassfication.(source: author's elaboration)

	LEED			ASGB		
	Prereq. Term	Credit Term	Credit	Prereq	Credit Term	Credit
Materials and Design	1	6	13	13	13	142
Energy	3	4	25	6	7	68
Water	3	5	14	3	11	112
Transportation	0	4	4	4	4	32
Indoor Environmental	2	7	13	7	8	72
Outdoor Environmental	0	4	6	3	10	117
Location	0	4	12	2	2	15
Management	2	5	12	2	5	42

Table 5.6: Credits distribution.(source: author's elaboration)

5.4.2 Comparative method

A comparative analysis will be carried out after the classification is completed: the impact and importance of the corresponding sections will be determined by calculating the relative significance indexes of each section, and a comparative analysis will be carried out between the two standards.

Sdandrad	ASGB 2019	LEED v4.1 BD+C
Calculation principles	Specific indicators accounting for the proportion of ratings in the rating system	
Calculation formula	$RSI = \sum \left(\frac{C_i}{T} \times 0.6 + \frac{Q}{N} \times 0.4 \right)$	$RSI = \sum \left(\frac{C_i}{T} \times 0.2 + \frac{Q}{N} \times 0.8 \right)$
Publicity Notes	RSI is the relative importance indicator K; Ci is the highest design score for the grade item i of K; T is the overall score of the system; Q is the number of prerequisite items of K; N is the total number of prerequisite items in the system.	
Weight description	In ASGB 2019, the total score value of the prerequisite item is 400 points, and the total score value of the scoring item is 600 points. Therefore. According to the score ratio, the weight coefficient of the prerequisite item calculation part of the formula is 0.4, the weight coefficient of the scoring item calculation part is 0.6. In LEED v4.1 BD+C, the prerequisite item is not given a score, As there is not clearly divided into the score ratio of the prerequisite item and the scoring item, the weight coefficient of the prerequisite item calculation part of the formula is 0.8 according to the proportion of the number of scoring items and prerequisite items, and the weight coefficient of the calculation part of the scoring item is 0.2. LEED of "Site and Transport" score adds up to 32 points, but the section is worth 16 points, which is calculated by dividing score by 2.	

Table 5.7: RSI calculation method for the rating system.(source: author's elaboration)

5.4.3 Overall Analysis

The relative importance (RSI) in the new evaluation sector of ASGB 2019 and LEED v4.1 BD+C (NC) is shown as Figures 5.3 and 5.4. The RSI of the ASGB 2019 items is, from largest to smallest,: Materials and Design, Outdoor Environmental, Indoor Environmental, Water, Energy, Transportation, Management, Location; The RSI of the LEED v4.1 BD+C(NC) indicator is: Energy, Water, Indoor Environmental, Management, Materials and Design, Location, Outdoor Environmental, Transportation.

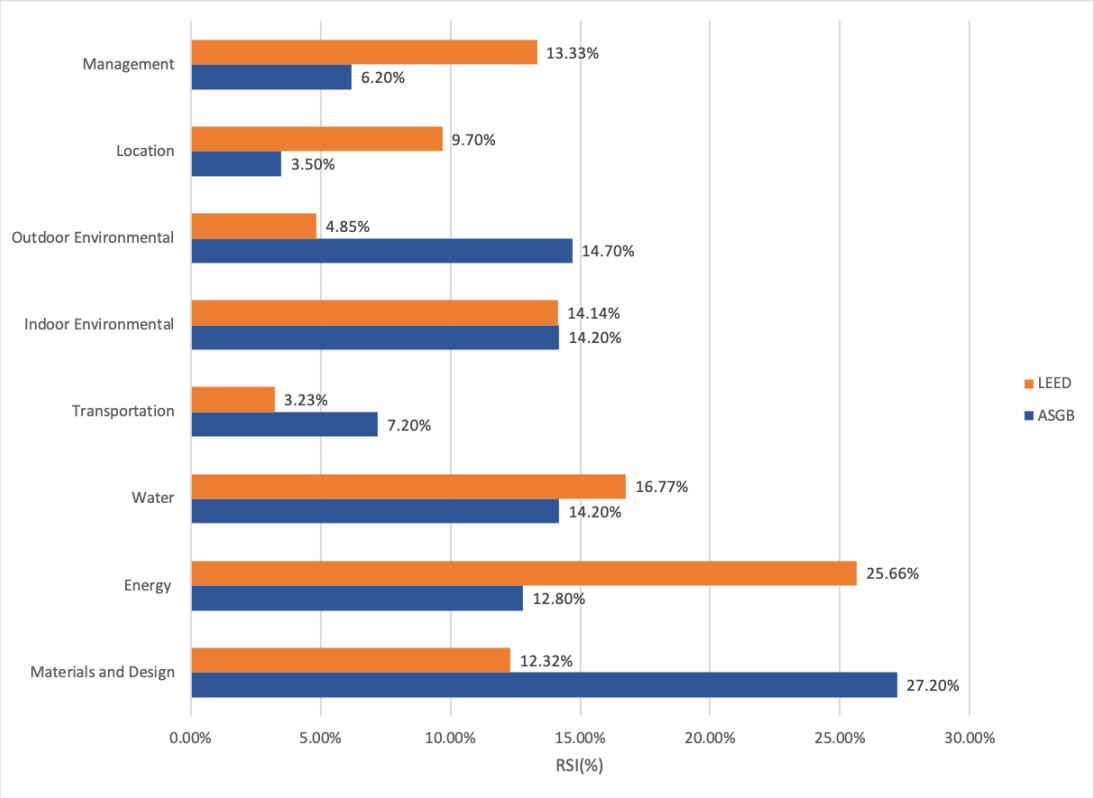


Figure 5.3: RSI for evaluation items(a).(source: author's elaboration)

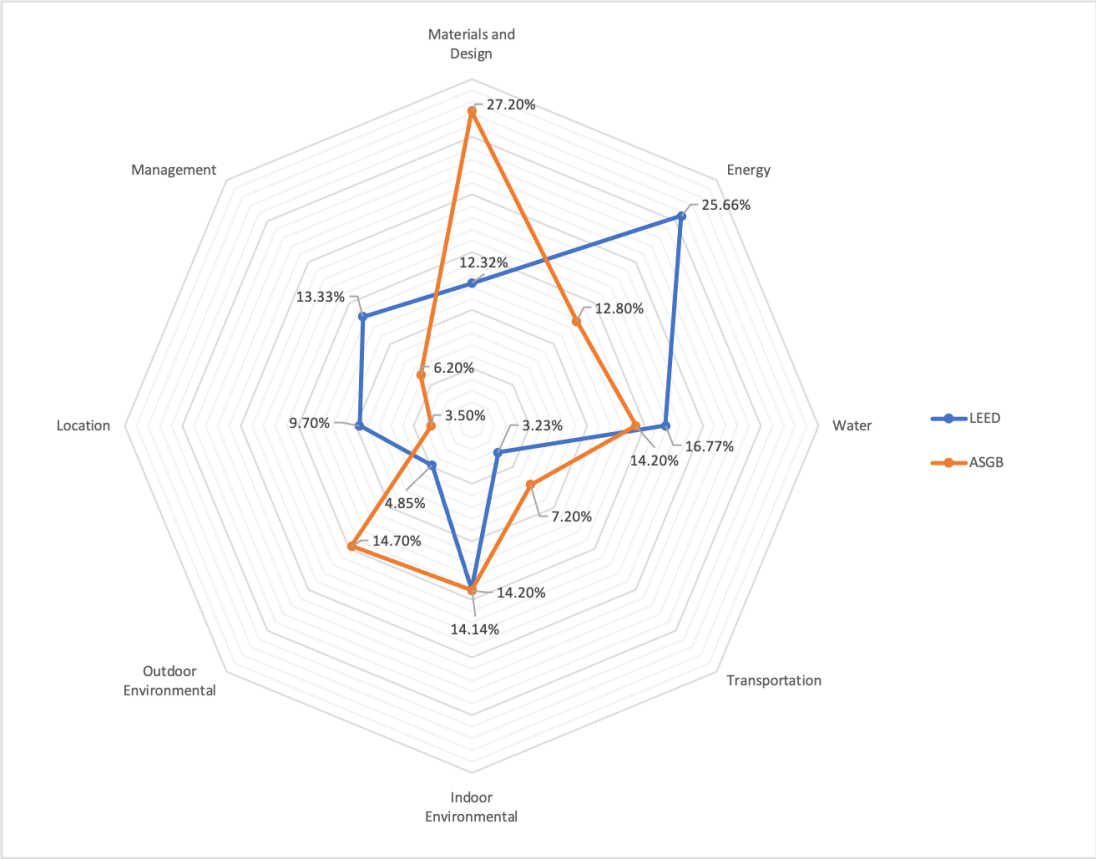


Figure 5.4: RSI for evaluation items(b).(source: author's elaboration)

It can be seen that these two evaluation items attach high importance to Materials and Design, Indoor Environment and Water. Less emphasis is placed on Transport and Location. In addition, Materials and Design, Outdoor Environmental, Energy, and The importance of these parts of Management fluctuates widely. Although Materials and Design has a large RSI in both standards, the RSI of ASGB 2019 is much larger than that of LEED. Energy is the most valued indicator in LEED, while it ranks only 5th in ASGB. Outdoor Environmental is the second most important indicator in ASGB, but less important in LEED. Management is the fourth most important indicator in LEED, but less important in ASGB.

From this, we can see Materials and Design, Indoor Environmental, Water and Energy, these aspects are the focus of the evaluation of the two standards, and there are many detailed terms and requirements for these aspects. Because the impact of materials and energy on green buildings is the main part, and it is also a strong aspect to improve and reflect the performance of green buildings, it will account for a large proportion of the evaluation score. Several other aspects that differ greatly reflect the difference in the focus of the two standards.

5.4.4 Materials and Design

	LEED v4.1 BD+C (NC)	ASGB 2019
Terms	MR1 Storage and Collection of Recyclables MR2 Building Life-Cycle Impact Reduction MR3 Environmental Product Declarations MR4 Sourcing of Raw Materials MR5 Material Ingredients MR6 Construction and Demolition Waste Management	4.1.2; 4.1.3; 4.1.4; 4.1.5;4.1.6; 4.1.7; 4.1.8; 4.2.1; 4.2.2; 4.2.3; 4.2.4; 4.2.6; 4.2.7; 4.2.8; 4.2.9; 5.1.7; 5.2.2; 7.1.8; 7.1.9; 7.1.10; 7.2.15; 7.2.16; 7.2.17; 7.2.18; 8.1.5;8.1.7
Prereq. term	1	13
Credit term	6	13
scorce	13/99	142/1000
RSI	12.32%	27.20%

Table 5.8: Summary of Materials and Design category.(source: author's elaboration)

Materials and Design is the most important part of ASGB 2019 and LEED v4.1. Both standards address the selection of materials, material recycling, and the restriction of hazardous materials.

The difference is that ASGB 2019 pays more attention to the durability of materials and the requirements for the structure and design of buildings, so as to achieve the purpose of saving materials, covering facility installation and maintenance, safety measures and intelligent services aspects. What makes ASGB 2019 special is the addition of waste sorting facilities, which is in line with the current situation of the consideration of building a resource-saving society. LEED v4.1 indicators are carefully divided, and in addition to the above standards, the con-

sideration of the environmental impact of building materials is added, and the impact content of the building life cycle assessment is specified in detail.

Compared with LEED v4.1, ASGB can consider strengthening research on material recycling, regulating the use of refrigerants, lead-mercury hazards and chemicals, and considering adding and valuing building life cycle assessment in future versions.

5.4.5 Energy

	LEED v4.1 BD+C (NC)	ASGB 2019
Terms	EA2 Minimum Energy Performance EA3 Building-Level Energy Metering EA4 Fundamental Refrigerant Management EA6 Optimize Energy Performance EA7 Advanced Energy Metering EA9 Renewable Energy EA10 Enhanced Refrigerant Management	6.2.6; 7.1.1; 7.1.2; 7.1.3;7.1.4; 7.1.5; 7.1.6; 7.2.4; 7.2.5; 7.2.6; 7.2.7; 7.2.8; 7.2.9
Prereq. term	3	6
Credit term	4	7
scorce	25/99	68/1000
RSI	25.66%	12.80%

Table 5.9: Summary of Energy categories.(source: author's elaboration)

Energy is the most important indicator of LEED v4.1, and it is also one of the indicators that ASGB 2019 attaches more importance to. Both standards use energy consumption monitoring and metering equipment to achieve the purpose of reducing energy consumption, and both encourage the use of renewable energy.

The difference is that the Energy part does not account for a large proportion of the score in ASGB 2019, but its items are large, involving energy consumption sub-metering, energy zoning, equipment energy saving, etc... But its specific requirements are not detailed enough and too subjective compared with LEED. For example, in ASGB, 7.1.3 "The temperature setting standard of indoor transition zone shall be rationally lowered" does not give a specific standard of "rational-

ity" for achieving the corresponding standard. In the "Energy Performance" of LEEDv4.1, the requirements for carbon emission calculation are proposed: In addition to the cost of energy consumption, the evaluation of greenhouse gas emissions has been added. The aim is to understand greenhouse gas emissions from building energy use and to prioritize building emission reductions, which are essential to combat climate change. ASGB 2019 only adds carbon emission requirements to the bonus "Promotion and Innovation", and does not specify the requirements.

5.4.6 Water

	LEED v4.1 BD+C (NC)	ASGB 2019
Terms	SS5 Rainwater Management WE1 Outdoor Water Use Reduction WE2 Indoor Water Use Reduction WE3 Building-Level Water Metering WE4 Outdoor Water Use Reduction WE5 Indoor Water Use Reduction WE6 Optimize Process Water Use WE7 Water Metering	5.1.3; 5.2.3; 5.2.4; 5.2.5;6.2.8; 6.2.11; 7.1.7; 7.2.10; 7.2.11; 7.2.12; 7.2.13; 8.1.4; 8.2.2; 8.2.5
Prereq. term	3	3
Credit term	5	11
scorce	14/99	112/1000
RSI	16.77%	14.20%

Table 5.10: Summary of Water categories.(source: author's elaboration)

The RSI scores of the two standards are similar for the Water part, and the content of the indicators is also relatively similar, involving water measurement, water loss reduction, water conservation and reuse. Water resources facilities are gradually improving the rate of water conservation, but there is no new idea of water conservation. The two standard water conservation standards are similar.

The difference is that LEED v4.1 focuses on water use reduction through facilities and appliances, installing water meters to measure water use; In addition

to combining the evaluation indicators of LEEDv4.1, ASGB also adds items such as water quality and water storage facilities. In the "Energy Performance" item of LEEDv4.1, the requirements for carbon emission calculation are proposed: In addition to the cost of energy consumption, the evaluation of greenhouse gas emissions has been added. The aim is to understand greenhouse gas emissions from building energy use and to prioritize building emission reductions, which are essential to combat climate change. ASGB 2019 only adds carbon emission requirements to the bonus "Promotion and Innovation", and does not specify the requirements.

5.4.7 Transportation

	LEED v4.1 BD+C (NC)	ASGB 2019
Terms	LT5 Access to Quality Transit LT6 Bicycle Facilities LT7 Reduced Parking Footprint LT8 Electric Vehicles	4.2.5; 6.1.1; 6.1.2; 6.1.3; 6.1.4; 6.2.1; 6.2.2; 7.2.3
Prereq. term	0	4
Credit term	4	4
scorce	4/99	32/1000
RSI	3.23%	7.20%

Table 5.11: Summary of Transportation categories.(source: author's elaboration)

The Transportation section is not a high RSI value for both standards, and it is not a very important aspect. Both address accessibility design and parking spaces, emphasizing accessibility, both in public spaces and in public transport.

Due to the large number of motor vehicles in the United States, the "LT 6 Bicycle Facilities" in LEED v4.1 encourages the use of bicycles; the "LT7 Reduced Parking Footprint" limits the parking area;"LT8 Electric Vehicles" encourages the use of green energy vehicles, thereby reducing the environmental pollution. Due

to the large residential density in China, unlike the practice of parking cars on the ground in the United States, most vehicles are parked in underground garages, so the indicator of underground garages is added. A special feature of ASGB 2019 is the addition of all-aged public spaces, which is in line with the current situation of considering the ageing society in China.

5.4.8 Indoor Environmental

	LEED v4.1 BD+C (NC)	ASGB 2019
Terms	EQ1 Minimum Indoor Air Quality Performance EQ2 Environmental Tobacco Smoke Control EQ3 Enhanced Indoor Air Quality Strategies EQ4 Low-Emitting Materials EQ7 Thermal Comfort EQ8 Interior Lighting EQ9 Daylight EQ10 Quality Views EQ11 Acoustic Performance	5.1.1; 5.1.2; 5.1.4; 5.1.5; 5.1.6; 5.1.8; 5.1.9; 5.2.1; 5.2.6; 5.2.7; 5.2.8; 5.2.9; 5.2.10; 5.2.11; 6.2.7
Prereq. term	2	7
Credit term	7	8
scorce	13/99	72/1000
RSI	14.14%	14.20%

Table 5.12: Summary of Indoor Environmental categories.(source: author's elaboration)

Both standards contain restrictions on smoke control, noise, lighting, natural lighting, thermal comfort, and air quality in indoor environments. ASGB 2019 includes requirements for shading and air quality in underground garages compared to LEED v4.1.

5.4.9 Outdoor Environmental

Both standards address the heat island effect and the impact of light pollution on the site.

	LEED v4.1 BD+C (NC)	ASGB 2019
Terms	SS3 Protect or Restore Habitat SS4 Open Space SS6 Heat Island Reduction SS7 Light Pollution Reduction	6.2.5; 7.2.1;7.2.2; 8.1.1; 8.1.2; 8.1.3; 8.2.1; 8.2.3; 8.2.4; 8.2.6; 8.2.7; 8.2.8; 8.2.9
Prereq. term	0	3
Credit term	4	10
scorce	6/99	117/1000
RSI	4.85%	14.70%

Table 5.13: Summary of Outdoor Environmental categories.(source: author's elaboration)

LEED v4.1 focuses on the development and protection of the external environment. ASGB 2019 mainly highlights environmental livability, that is, site ecology, landscape and outdoor physical environment. However, the objectivity of the indicators is insufficient, and some of the items lack specific standards and details in the evaluation, such as the scoring point in 8.2.1 "Site ecological environmental", which only gives the means of ecological protection, without giving more specific criteria for meeting the standard.

The difference in the importance of the two standards in terms of Outdoor Environmental is due to the fact that ASGB 2019 strengthens the requirements for the comfort and health of the occupants, and therefore the safety and health of the occupants during the use of the external space are planned.

5.4.10 Location

In the Location section, LEED v4.1 has a larger RSI value. LEED v4.1 focuses on site selection, site contamination control and site protection, with a particular reference to brownfield remediation in "LT2 Sensitive Land Protection", which is not covered in ASGB 2019. ASGB 2019 focuses more on the convenience and protection of the site.

	LEED v4.1 BD+C (NC)	ASGB 2019
Terms	LT1 LEED for Neighborhood Development Location LT2 Sensitive Land Protection LT3 High Priority Site and Equitable Development LT4 Surrounding Density and Diverse Uses	4.1.1; 6.2.3; 6.2.4; 8.1.6
Prereq. term	0	2
Credit term	4	2
scorce	12/99	15/1000
RSI	9.70%	3.50%

Table 5.14: Summary of Location categories.(source: author's elaboration)

5.4.11 Management

	LEED v4.1 BD+C (NC)	ASGB 2019
Terms	SS1 Construction Activity Pollution Prevention SS2 Site Assessment EA1 Fundamental Commissioning and Verification EA5 Enhanced Commissioning EA8 Grid Harmonization EQ5 Construction Indoor Air Quality Management Plan EQ6 Indoor Air Quality Assessment	6.1.5; 6.1.6; 6.2.9; 6.2.10; 6.2.12; 6.2.13; 7.2.14
Prereq. term	2	2
Credit term	5	5
scorce	12/99	42/1000
RSI	13.33%	6.20%

Table 5.15: Summary of Management categories.(source: author's elaboration)

Management is the 4th priority indicator in LEED v4.1 while of less importance in ASGB 2019. The two standards have different emphases.

The LEED v4.1 management section runs through the life cycle of the building, involving service management from the early stage of the project, mid-term trial and handover and service management in the later stage of use. And the scoring items have detailed evaluation criteria and technical details; ASGB 2019 mainly focuses on the management of slogans during the use of buildings, with little involvement in the design stage of the building, and increases the control of the overall energy consumption of the building by increasing the control indicators for monitoring the use of various resources. However, some of these items

are too subjective and do not have specific and detailed criteria, such as the scoring item of "relevant facilities have sound operating procedures and emergency plans" in 6.2.10, but did not give specific operating procedures, emergency plans and other key points, the score is more subjective.

5.4.12 Other items

Several categories that are not listed in the above analysis are discussed below: "Promotion and Innovation" in ASGB 2019, "Innovation", "Regional Priority" and "Integrative Process" in LEED v4.1.

"Promotion and Innovation", as a bonus item in ASGB 2019, aims to encourage projects to achieve higher green building standards or innovation, in order to improve the performance of green buildings and create a healthier and more comfortable environment. This includes higher requirements for reducing energy consumption in terms of energy, adding points to buildings suitable for regional characteristics in terms of culture, and encouraging the use of new technologies (BIM, carbon emission calculations, etc.).

"Integrative Process" to support high-performance, cost-effective, equitable project outcomes through an early analysis of the interrelationships among systems.[8] The Integrative Process has great flexibility and includes social equity, public health, and site selection decisions. "Innovation" is to encourage projects to achieve exceptional or innovative performance to benefit human and environmental health and equity.[8] Sometimes, innovative strategies can enable building performance to far exceed existing specifications. "Regional Priority" is to consider that green building design is often affected by regional climatic characteristics and resource and environmental conditions, such as water resource distribution, sunshine conditions, climatic conditions, etc. "Regional Priority" encourages projects to adopt a regionalized design approach that highlights lo-

cal resources and environmental strengths to address priority issues such as the environment, social equity and public health.

It can be seen that both standards put forward higher expectations for reducing energy consumption by improving the corresponding resource and energy standards. ASGB 2019 does not have separate "Integrative Process" and "Regional Priority" sections compared to LEED. However, there is a related mention in the bonus item "Promotion and Innovation", the requirements for buildings suitable for regional characteristics are put forward in "9.2.2 Regional Architectural Culture". "9.2.6 BIM Technology" sets out the requirements for the integrated design of buildings at all stages. Of course, ASGB 2019 is only required in the bonus item and is not detailed, but it is clear that "Integrative Process" and "Regional Priority" will become one of the future standard development trends.

Chapter 6

Summary and Conclusion

6.1 Summary and Conclusion

Through the analysis of the above chapters, the following summary is made:

1) LEED has gone through multiple editions, updated almost every 2-3 years, covering almost all building types and stages. The latest LEED v4 Version has an advanced nature for the development of green buildings.

   - In terms of overall content: the relevant requirements of "Integrative Process" and "Regional Priority" are proposed, and flexible requirements are put forward for early designs and different regions, taking into account the performance requirements of green buildings and the development of different regions.
   - In terms of evaluation of indicators in each chapter:
     - Materials and resources: The Whole Building Life Cycle Assessment (WBLCA) is used to reduce the impact of materials on the whole building life cycle. Furthermore, the composition and source of materials and the treatment and utilization of building materials waste are strictly controlled.

- Resource: Reduce energy consumption by monitoring and managing energy consumption and design calculations accordingly (energy cost calculation or greenhouse gas emission calculation) and encourage the use of renewable energy.
- Indoor environment: the monitoring of indoor harmful gases, and water, sound, light and other indoor physical environment are strictly required and controlled, and equipment monitoring and detailed design calculations are used to control and improve the quality of indoor environment.

2) The formulation of ASGB is constantly improved with people's understanding of green buildings, the development of science and technology and the scientific nature of evaluation. The revision of ASGB from 2006 (first edition) to 2014 to the present 2019 edition is a process of continuous development and improvement of this standard, and ASGB 2019 sets out updated requirements for the implementation of green buildings.

   - In terms of scoring methodology: ASGB 2019 adopts a direct scoring method, which makes green building evaluation more intuitive and convenient and easy to operate.
   - In terms of overall content updates: ASGB 2019 has added more content to the safety and durability chapter, reflecting the people-oriented purpose.
   - In terms of the revision of items in each chapter:
     - Health: The new standard adds the monitoring of indoor harmful gas types and the control of indoor physical environments such as water, sound, and light in the health and comfort chapter, reflecting the importance of human health.

- Energy saving: With the advancement of technical means, the new standard proposes to use intelligent ways to monitor and manage energy consumption, so that energy management is more intuitive, convenient, scientific and effective. All these reflect that the new standards are more scientific and keep pace with the times in the process of improvement.

3) Through the content analysis of the green building assessment standards in China and the United States, the differences between ASGB and LEED are summarized:

- In addition to geographical and country differences, the biggest difference between the two standards stems from the differences in their issuers:
  - LEED is a commercial standard developed and issued by The U.S. Green Building Council, which represents the precision of green building technology. And more consideration is the development of technology and the improvement of energy efficiency. And the speed of replacement is very fast, the new version updates in every two or three years according to the development of technology and the need.
  - ASGB is a national standard set by the Chinese government. As a national standard, in addition to technical and performance requirements, the standard will take more into account the different situations of the development of various regions, especially the relatively backward development of regions. Therefore, the relative standard will relatively reduce the requirements for technology and performance. And because it is a national standard, revision

and update take a long time, the update frequency is slow, and there is a certain lag.

- Apart from the issuers, differences in content between items can be summarized as:
  - Land Use and Ecology: ASGB 2019 focuses on land conservation and environmental livability in "land use", while LEED v4.1 focuses more on ecological assessment and restoration. The difference in this regard is mainly due to the fact that China's per capita land resources are less, and the efficient use of land is more important. So, in ASGB 2019, not only the land use above the project is restricted, but also a plus item is set to promote the rational use of underground space.
  - Materials and Energy: LEED V4.1 covers the assessment of energy emissions and life cycle carbon consumption in the production of materials, but ASGB 2019 currently covers less of it.
  - Management: Management has more content in LEED, and the management section runs through the whole life cycle of the building, involving service management from the early stage of the project, the mid-term trial and handover and the later use of the project. The content covered in ASGB 2019 is also covered in addition to the constraints on the early stage of the project, but the relative score setting is less than that of LEED.

6.2 Recommendations for ASGB

Through the comparative analysis and summary of the content of ASGB 2019 and LEED v4.1, the following suggestions are put forward for the future development of China's green building assessment standards:

6.2.1 Content suggestions

- Management: The management of green buildings should run through the entire life cycle of green buildings, namely the design stage, construction stage, completion stage and operation stage. ASGB 2019 does not make too many mandatory requirements in the design and construction management part, and only recommends the implementation of the embodiment in the bonus items. It is suggested that relevant content be added to the basic items to better reflect the whole process management requirements of green buildings.

- Energy: Reducing carbon emissions is the content that also needs to be considered after reducing energy consumption. Due to the improvement of green energy technology, the value of energy consumption cannot better reflect the environmental impact caused by the combustion of oil, coal, etc... Therefore, the detection and control of carbon emissions need to be gradually considered in the basic items of ASGB, so as to explore the environmental impact of green buildings more accurately in the process of design, construction, and use.

- Transportation: ASGB 2019 currently only deals with the construction of public transport stations in the "Green Mobility" section and has not yet covered measures to promote users' preference for green travel. Combined with the successful implementation of "shared bicycles" in China, it is recommended that green buildings consider the new needs of users when cycling, so that green travel becomes the priority choice for people when travelling.

6.2.2 Promotion advice

- Climate differences: Due to China's large land area, wide span from north to south and east to west, it has different temperature zones such as cold temperate zone, middle temperate zone, warm temperate zone, subtropical, tropical, plateau climate zone, etc. If in order to adapt to different climate zones, different adjustments to ASGB will produce too many substandards, resulting in the difficulty of reading and finding. Therefore, it is recommended that ASGB control the actual use effect of the building in the promotion process. The rapid development of simulation software can simulate the final energy consumption and temperature of the building at the design stage. With the help of simulation technology, the use of green buildings in different temperature zones to control the performance of green buildings can become one of ASGB's measures to cope with different climates.

- Economic development: Economic development differences are also one of the obstacles in the development process of green buildings. Because green building technology is still in the research and development stage, the cost is still high. So the development of green buildings in some areas with poor economic development may bring certain economic pressure. In order to make ASGB adapt to different economic development regions, it is recommended to set different index weights according to the per capita income of different regions. In addition to energy consumption problems in economically developed areas, transportation problems will become one of the main problems, and the "Green Building Evaluation Standards" can appropriately improve the weight score of "transportation" indicators in some regions; For areas with slower economic development, the weight of the

energy category can be appropriately increased, and in areas with slower economic development, natural resources are relatively richer, and the score of the construction of natural resources (timber, etc.) can be added to the innovation item to supplement the gap caused by economic development.

- Urban-rural differences: Due to the rapid development of urbanization, urban heat island effects and other phenomena frequently occur. So ASGB has added extra points for measures to reduce heat islands in 8.2.9. But in some rural areas, the heat island phenomenon is not obvious, and there will be certain difficulties in the implementation of this article. And due to the difference in the number of people, the plot ratio, green space rate, etc. are limited to certain differences between urban and rural areas, so it is somewhat difficult to use only a single standard to limit. So it is recommended to set up an independent green building evaluation standard sub-volume for rural areas to increase the adaptability of ASGB in the promotion process.

References

[1] A. K. Jorgenson, S. Fiske, K. Hubacek, J. Li, T. McGovern, T. Rick, J. B. Schor, W. Solecki, R. York, and A. Zycherman, "Social science perspectives on drivers of and responses to global climate change," *Wiley interdisciplinary reviews. Climate change*, vol. 10, no. 1, p. e554, 2019.

[2] D. T. Doan, A. Ghaffarianhoseini, N. Naismith, T. Zhang, A. Ghaffarianhoseini, and J. Tookey, "A critical comparison of green building rating systems," *Building and Environment*, vol. 123, pp. 243–260, 2017.

[3] "Green buildings." `https://www.epa.gov/land-revitalization/green-buildings`, 6 2022. U.S. Environmental Protection Agency.

[4] "What is green building?." `https://www.worldgbc.org/what-green-building`, 6 2022. World Green Building Council.

[5] "Green building and sustainability (superseded) (tg15/2018)." `https://www.bsria.com/uk/product/NrgQaD/green_building_and_sustainability_superseded_tg152018_a15d25e1/`, 9 2018. The Building Services Research and Information Association.

[6] "Assessment standard for green building." China Academy of Building Research., 2019. GB/T 50378-2019.

[7] "Leed." `https://www.usgbc.org/`, 2022. U.S. Green Building Council.

[8] "Leed v4.1 building design and construction." https://www.usgbc.org/, 2021. U.S. Green Building Council.

[9] "Evaluation standard for green building." Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD), 2014. GB/T 50378-2014.

[10] "Evaluation standard for green building." Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD), 2006. GB/T 50378-2006.

[11] "Green building label statistics." www.cngb.org.cn. Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD).

[12] "Ctbuh year in review: Tall trends of 2020." https://www.skyscrapercenter.com/year-in-review/2020/data, 2020. Council on Tall Buildings and Urban Habitat.

[13] J. Kriss, "From a simple idea to a several-hundred-billion-dollar industry." https://www.usgbc.org/articles/simple-idea-several-hundred-billion-dollar-industry, 2022. U.S. Green Building Council.

[14] J. Kriss, "Part 2: A green building explosion (2003-2009)." https://www.usgbc.org/articles/part-2-green-building-explosion-2003-2009, 2014. U.S. Green Building Council.

[15] J. Kriss, "Part 3: Challenges and opportunities (2010-present)." https://www.usgbc.org/articles/simple-idea-several-hundred-billion-dollar-industry, 2014. U.S. Green Building Council.