Problems and Countermeasures in the Sustainable Development of Green Buildings in China

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Abstract
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The development of green buildings is crucial in achieving the objective of carbon peaking and carbon neutrality because the construction industry accounts for 40% of CO2 emissions and 36% of the world's energy consumption. The sustainability of green buildings is examined in this thesis, which also serves as a resource on how to encourage their sustainable development by informing readers on the current status of green buildings in China. And this thesis is provided as advice for professionals in the construction industry and information on green buildings for non-specialists.

The thesis begins by examining the characteristics of green buildings, their current stage of development, and the issues they face. It then makes use of literature research and comparative analysis to examine the factors that have an impact on the sustainability of green buildings from various stages and both internal and external perspectives.

The thesis suggests that to improve the sustainable development of green buildings in China, it is necessary to increase the sustainability of the buildings themselves at all stages and to promote the sustainable development of green buildings in China from five aspects: policy, market, technology, management, and social awareness. It also offers specific recommendations for countermeasures.

Keywords Green building, sustainable development, sustainable utilization, countermeasures and suggestions
Pages 51 pages

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1 Introduction

The world is developing rapidly in the direction of industrialization, informatization, urbanization and new rural construction, which has brought unprecedented prosperity to the construction industry, contributing greatly to the national economy and GDP while also providing housing security for the people. However, the negative effects of high consumption of resources and energy, high environmental pollution, high investment, and low income are becoming increasingly prominent.

1.1 Background

In China, under the "no speculation in housing" policy and the carbon peak target, China's total building energy consumption has dropped to 22% of total social energy consumption, which is still a high percentage despite the significant decline (China Building Energy Conservation Association, 2021). This does not include the energy consumption of building material production and building operation itself, which, if converted into standard coal, is more than 1 billion t. WU's studies show that the energy consumption of buildings in 2018 alone exceeded 1.2 billion t of standard coal, which is 13.87 times the energy consumption published in the China Statistical Yearbook. Meanwhile, over the 13 years from 2005 to 2018, the energy consumption of the buildings during their whole life cycle of buildings increased at a rate of more than 6%, reaching 2.141 billion t of standard coal in 2018. (WU, 2022)

With the increasing awareness of the need to protect the environment, the demand for sustainable development has been gradually rising globally. To achieve sustainable use of energy as well as materials and sustainable development of economy and society, it is necessary to pay attention to improving the efficiency of resource and energy utilization. In this context, the green building concept has become the best choice for the construction industry.

Unlike traditional buildings, green buildings are a complex and long-term system based on the concept of sustainable development. They need to meet conditions that can reduce

pollution, create a comfortable and healthy environment, protect the environment, and conserve resources to achieve people's objective needs for practicality and efficiency as well as their physiological needs for health and closeness to nature, and to achieve harmony among people, buildings, and the ecological environment throughout the building's life cycle, including the design, construction, use, demolition, and other phases. Overall, the concept of green building is defined by three clear themes: reducing the pressure on the natural environment and living resources; creating a comfortable and safe living environment; as well as integrating symbiotic and harmonious development with nature.

In the construction industry, to ensure sustainable development, people need to deal with the balanced relationship between the development of real estate enterprises, economic benefits, environmental benefits (Mei , 2021). But in the development of green building economy three contradictions are still very prominent, such as immature green building technology, long return on investment, low public awareness and other issues. They are the key problems of sustainable development of green building, which makes the green building economy cannot achieve the expected results. For this reason, the sustainable development of green building economy needs to be based on the scientific concept of development, and moreover, the government and society need to work together to give more support to its development. The goal is to realize the harmonious and sustainable development of green building.

1.2 Literature review

Research over the past 20 years has provided information on the development of green buildings worldwide, and currently, experts and scholars are also conducting research on the meaning of building sustainability (WU, 2022), which is described mainly in three dimensions: environmental, economic, and social (Mei , 2021). In addition, some scholars believe that management sustainability (Luodan, 2019) and technological sustainability (Li, 2021) are also important aspects of building sustainability.

Green buildings are constantly evolving, and to maintain sustainability, the standard systems of green buildings around the world have changed accordingly to follow the times (Devine,

McCollum, & Orlova, 2022), with the latest version of China's green building standards going through three revisions being issued in 2019. (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2020). Under the consideration of protecting the environment and saving resources, the Chinese government attaches great importance to green building and encourages numerous policies (Liu , He, Hu, & Liu, 2019), among which different types of policies have different impacts on green building innovation, but the significance is the same (Fangjia & Lihua, 2021). China's green buildings are developing under national policy incentives, but there is a lack of high-star buildings (Xing, 2021) and the promotion efficiency varies from region to region leading to uneven development between regions (Chen, Chan, Darko, & Gao, 2022). This situation is due to the different levels of attention given to green buildings by local governments (Wei, Chuan, Hao, & Hongjun, 2022), as well as the role of developers and consumers in the crossfire (Qiao, Dong, & Ju, 2022).

Improving the sustainability of green buildings can be done both in terms of the green building itself and the external influences. For the green building itself, it can be discussed in three stages: design, construction, and demolition, such as the selection of new building materials (Bäcklin, 2021) (Sha & Yang, 2021) (Schneider, 2022) (Jingjie, 2018),the application of sustainable energy (Baidu Encyclopedia, 2021) (Yutong, Lan, Siyan, Wenfeng, & Jintao, 2021), the application of building technology (Wikipedia, 2022) (Feng, Saliari, Gao, & Santamouris, 2022) (Anhui Gezhi Green Building Design Co., Ltd., 2019), the management of construction sites (Luodan, 2019) (Luochun & Youcai, 2004), the recycling of demolition construction waste, and so on. In terms of external promotion, the practical experience of green building energy-saving development in Germany (Yanfeng, 2020) and the United States (Yu, Li, & Xianchao, 2020) (Yanjie, Shicong, Wei, & Connelly, 2020) is selected. This is then combined with the development of Hebei Province in China (Hebei Provincial Department of Housing and Urban-Rural Development, 2020) to summarize the beneficial inspiration for promoting the sustainable development of green buildings in China.

2 Objective and limitations

Research over the past 20 years has provided a solid foundation for this thesis in terms of the development process of green buildings in China and researchers' summaries of past achievements and outlooks for the future. However, most of the existing research has remained at the level of strategic objectives, but there is a lack of in-depth research in terms of comprehensive analysis of the factors influencing sustainable building development and specific recommendations for countermeasures.

2.1 Scope of thesis

The purpose of this thesis is to offer relevant guidelines and tactics to help China implement sustainable green construction practices. The thesis focuses on practical ways to increase the sustainability of green buildings. Focusing on the characteristics and development status of green buildings, the difficulties encountered in the three major aspects of green buildings in China, namely policy and standard system, market and technology, and internal and external factors influencing green building sustainability. Based on this, it is further developed to provide insightful summaries and practical suggestions for fostering the growth of green buildings in China in terms of five different areas: policy, market, technology, management, and social awareness.

The main limitation of this thesis is that it is limited to making effective recommendations to promote the development of green buildings in China's provinces, which vary from province to province and are difficult to apply. The green buildings in the research objectives of this thesis are worthy of being called green buildings, and the direction of travel provided is only general and cannot be guaranteed to apply to the situation of each type of building. In the thesis, data from the last 20 years has been chosen for reference, and as it is secondary data, the data may be out of date resulting in conclusions that are not very accurate.

2.2 Research framework

The thesis is divided into eight main chapters. The research framework of the thesis is shown in Figure 1.

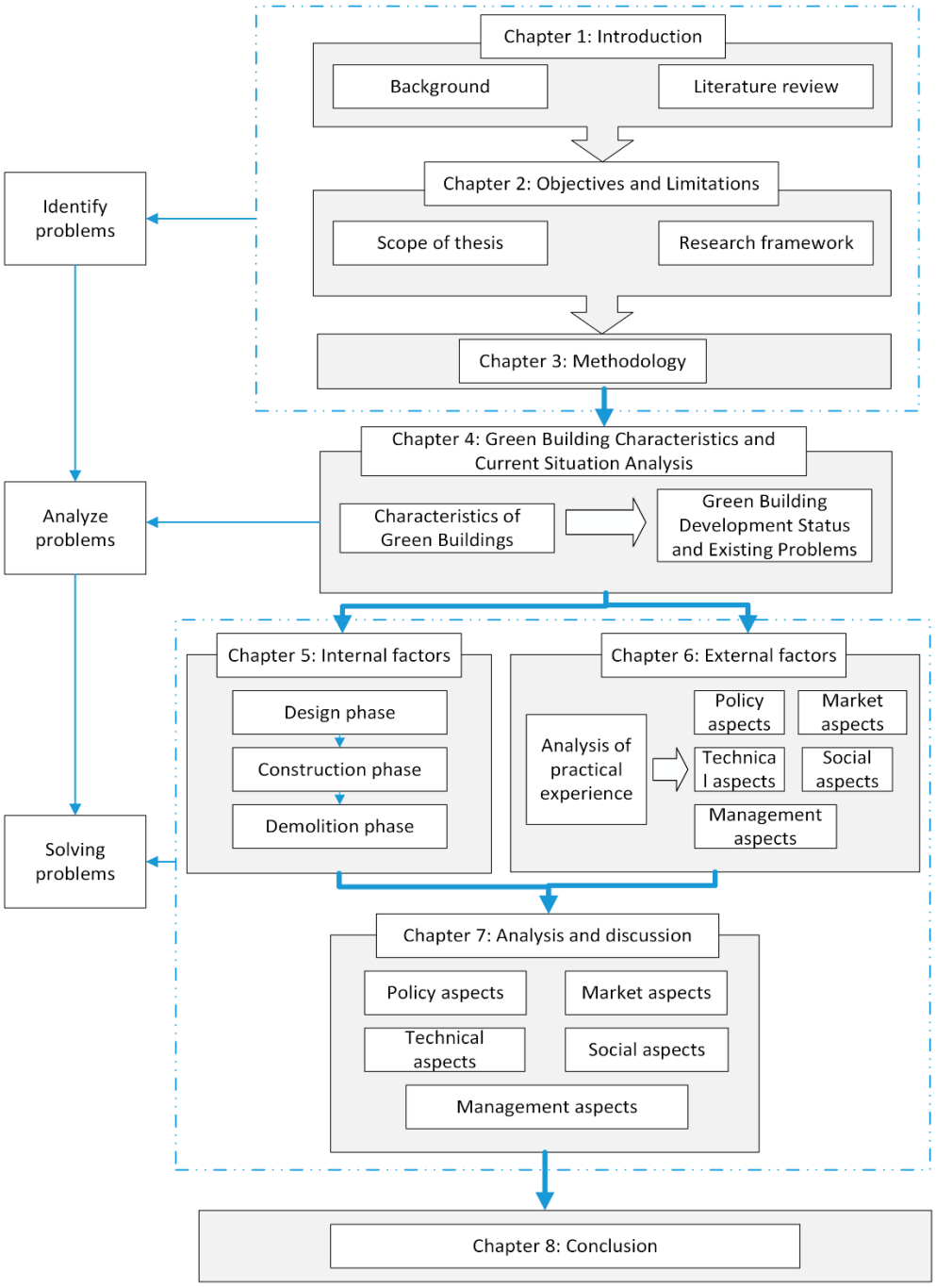

Figure 1 Thesis Framework Diagram

3 Methodology

The main research methods used in the thesis are literature and project research method, comparative analysis method, and summarization and generalization method.

3.1 Literature and project research method

Through published research articles and existing project data collection, collation, and analysis, it is possible to gain a deeper understanding of the current state of research and relevant achievements around green buildings, analyze the technical problems involved in green buildings, and summarize and analyze the factors affecting sustainable development.

3.2 Comparative analysis method

The thesis examines the development of green buildings in the United States and Germany to better understand the shortcomings of green buildings in China. Germany and the United States are leading the charge to promote building development globally, and their corresponding practical experience is valuable to study. China's Hebei Province has successfully promoted the development of green buildings by positively looking into appropriate energy-efficient structures and taking advantage of the region's climate advantages. Comparing the development of green buildings in three countries reveals similarities and differences in the development of green buildings.

3.3 Summarization and generalization method

Through an analysis of the practical experience accumulated in the development of green buildings in three different regions - Germany, the United States and Hebei Province, China - the findings are summarized to help make practical recommendations to promote the sustainable development of green buildings in China in the future.

4 Green building characteristics and current situation analysis

China's green building policies are being gradually implemented, standards and norms are being gradually established, and the building area and quantity are expanding, but its development is still hampered by issues such as imperfect policies and standard, insufficient market cultivation, and a backward technological level. As a result, a comprehensive examination of the characteristics of green building development, the current state of development, and the existing difficulties is required.

4.1 Characteristics of Green Buildings

Compared to ordinary buildings, green buildings are characterized by higher energy efficiency, a focus on the environment, the relationship between buildings and people, the level of technology, and the quality of personnel required.

4.1.1 Higher energy efficiency

Green buildings focus on improving energy efficiency at the design stage by reducing energy loss and reducing building energy consumption. The use of good performance envelope structures, windows and doors, ducts, and new air systems can reduce energy loss while safeguarding and optimizing the building's indoor thermal, acoustic, and wet environments, and improving the building's indoor air quality. Intending to reduce energy consumption, the rational use of renewable energy sources reduces dependence on fossil energy through a similar self-production and self-sales approach. (TACwin Company)

4.1.2 Focus on the relationship between the environment, building, and people

Green buildings pay great attention to the close relationship between the building itself and people and the environment at different stages of construction. In the design stage, the differences between the building and the climate and the region and the process of influencing each other are fully considered, so that the building itself is organically integrated with the environment, adapting to the local natural conditions while ensuring the

harmony and unity of the building and the environment, providing a healthy and comfortable living environment for the occupants. During the construction phase, the loss of natural resources such as materials and energy, as well as pollution, are minimized to reduce the cost of construction work and to improve and protect the environment at the construction site. In the maintenance and demolition stages, the recycling of materials allows the building to achieve a long-life cycle, high efficiency, and recycling materials, it really balancing the relationship between economic efficiency, and building performance, achieving the integration of nature and people's daily lives, and thus promoting the sustainable development of the construction industry.

4.1.3 High technical level and personnel quality requirements

To achieve the goal of high energy efficiency, livability, and environmental protection, not only is the level of refinement required in construction, but also the quality and performance of materials, products, and equipment are required to be higher. The key lies in whether the various systems can match each other and function in a coordinated manner. This requires an analysis of the suitability of the technology and the combination of various technologies and equipment to come up with a suitable design solution, rather than piling up various high technologies (Liu M. , 2017). These technologies (renewable energy systems, Intelligent and information system) and equipment (exhaust heat recovery device, rainwater recovery system) are interdisciplinary and cross-disciplinary, and it is a challenge to achieve the coordinated operation of the various systems, equipment, and technologies, which also requires a high level of expertise (Haifeng, 2017).

4.2 Green Building Development Status and Existing Problems

By analyzing the current state of development of green buildings in China, we can identify the problems that currently exist to solve them accordingly. The analysis is broadly based on policies, standards, markets, and technologies.

4.2.1 Current Situation of Green Building Development

From 1980 to 2018, China has successively promulgated policies and systems related to green building, which have a positive impact on driving the development of the green building as well as optimizing the built environment, with a total of 296 policies on the whole industry chain of green building promulgated independently or jointly by 35 institutions, including the Standing Committee of the National People's Congress, the State Council, the Ministry of Housing and Urban-Rural Development, the National Development and Reform Commission, and the Ministry of Commerce (Liu , He, Hu, & Liu, 2019). For example, in 2012, the central government issued two policies, "Implementation Opinions on Accelerating the Development of Green Buildings" and "Special Planning for the Development of Green Building Science and Technology," which directly promoted the explosive growth of green building policies in 2013 and laid the first solid foundation for the subsequent sustainable development of green buildings (Fangjia & Lihua, 2021).

1. The standards for green buildings are gradually improving.

At present, all countries in the world have introduced regulations to regulate green building standards, such as the US Green Building Evaluation System (LEED), the British Green Building Evaluation System (BREEAM), and the German Eco-Building Guidelines (DGNB) and so on. (Devine, McCollum, & Orlova, 2022). China's Green Building Evaluation Standard was first published in 2006 and has since been revised twice with a 2014 version and a 2019 version. The latest version is the Green Building Evaluation Standard numbered GB/T 50378-2019, which was approved by the Chinese Ministry of Housing and Urban-Rural Development on August 1, 2019 (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2020). The main technical contents of the revision are:

1. reconstructed the technical index system of green building evaluation;
2. adjusted the evaluation time node of green building;
3. increased the green building grade;
4. expanded the connotation of green building; and
5. improved the green building performance requirements.

The main content of the evaluation of this standard is the seven aspects of basic provisions, safety, and durability, health and comfort, the convenience of life, resource conservation, environmental livability, improvement, and innovation. According to the above requirements for scoring so that the green building should be divided into four levels: basic level, one star, two stars, and three stars. (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2020) The scoring criteria are shown in Figure 2.

Table 3. 2. 4 Scores of Green Building Assessment

	Basic score for prerequisite 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	200	100	100
Assessment score	400	100	100	100	200	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.

Figure 2 Scores of Green Building Assessment (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2020)

When all the requirements of the control items are met, the green building level should be basic. Figure 3 below shows the technical requirements to achieve a higher level, when the total score reaches 60, 70, and 85 respectively and the requirements of Figure 3 are met, the green building level should be one-star, two-star, and three-star, respectively.

Table 3. 2. 8 Technical Requirements of One-star, Two-star and Three-star Green Buildings

	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
	One-star grade	Two-star grade	Three-star grade
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 of 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*.

Figure 3 Technical Requirements of one-star, two-star, and three-star Green Buildings (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2020)

2. The government provides more policy support for green buildings.

Overall, China has established a policy system for green building development that combines mandatory policies with incentive measures. China has standard mandatory policies in public buildings, subsidized housing, government-invested buildings, and so on. In addition to a variety of incentive policy elements such as financial services, preferential land use, tax breaks (for green building construction and development projects), and financial incentives (such as subsidies for lighting products, renewable energy, solar energy, etc.), there are also

supporting systems in the areas of green energy, energy efficiency labeling, green energy, and heating systems.

In 2022, China's State Council issued "14th Five-Year Plan" Comprehensive Work Plan for Energy Conservation and Emission Reduction, proposing that by 2025, new urban buildings will fully implement green building standards. National energy consumption per unit of GDP will drop by 13.5% compared to 2020, total energy consumption will be reasonably controlled, total chemical oxygen demand, ammonia nitrogen, nitrogen oxides and volatile organic compounds emissions will drop by 8%, 8%, more than 10% and more than 10% respectively compared to 2020, and green planning and green construction will be comprehensively promoted. (State Department, 2022) last two years, provinces and cities are increasing their incentives, including Hebei Province, where the financial incentive for ultra-low energy consumption building projects has reached 400 yuan per square meter in 2020, with an incentive standard of no more than 12 million per project (China Academy of Building Research, 2020).

3. Green building projects are growing rapidly, but the development of green building projects with high star ratings is slow.

Since China officially launched the green building evaluation labeling process, the number of projects awarded the green building label has increased year after year. By the end of 2018, the proportion of green buildings in China's new civil buildings in urban areas had surpassed 40%, with a total of 9,190 projects awarded the green building evaluation label across 27 provinces, municipalities, and autonomous regions (Xing, 2021). The number of green building projects has increased exponentially and continues to rise. Figure 4 shows the annual growth of green buildings from 2008 to 2018.

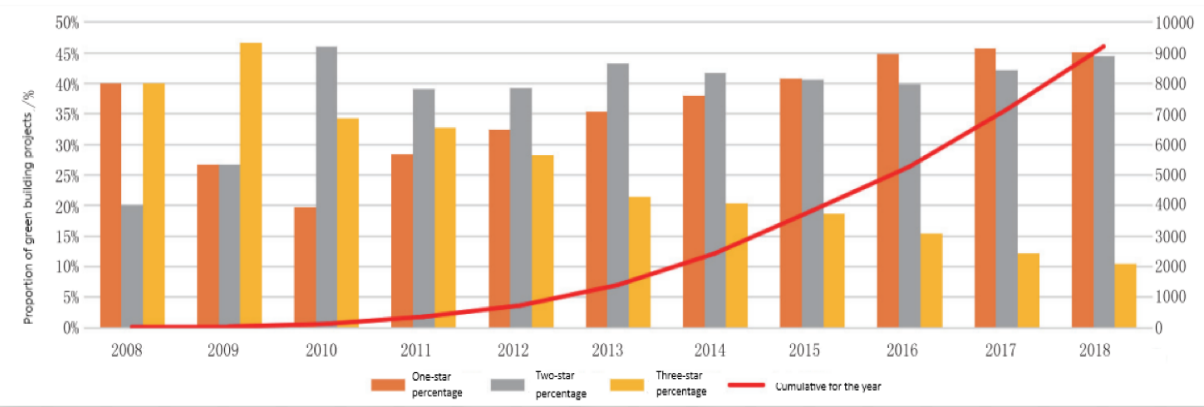

Figure 4 The development of green buildings year by year from 2008 to 2018 (Xing, 2021)

However, in terms of green building rating criteria, the number of projects awarded the one- and two-star green building label is generally on the rise, compared to the slow development of three-star green building projects, whose percentage has been steadily declining since 2009. This indicates that, despite more than a decade of development, China's green buildings are still only increasing in number, while the growth of high-star green buildings is slow.

4. The unbalanced development of green building between regions is obvious.

Figure 5 shows the spatial pattern of clusters in mainland China, and it can be concluded that the development of green buildings in China is uneven among regions. From the regional level, the number of green building projects in the eastern, central, and western regions has been growing steadily from 2008 to 2018, with the scale and growth rate of green building development in the eastern region being much higher than those in the central and western regions. In terms of the proportion of green buildings in each region, the proportion of green buildings in the eastern region has been decreasing year by year, while the proportion in the central and western regions has been increasing year by year, indicating to a certain extent that the development trend of green buildings is spreading from the east to the central and western regions. (Chen, Chan, Darko, & Gao, 2022)

At the provincial level, the province with the highest number of Green Building Mark certified projects is Jiangsu, with the top five provinces being Jiangsu, Shanghai, Guangdong,

Shandong, and Hainan. Many similarities exist between Jiangsu, Shanghai, and Guangdong, such as their coastal location and the prosperity of the local economy and culture. The coastal location boosts the local economy and allows for easy access to other areas. The prosperity of the local economy and culture ensures the GB's basic construction conditions. (Chen, Chan, Darko, & Gao, 2022)

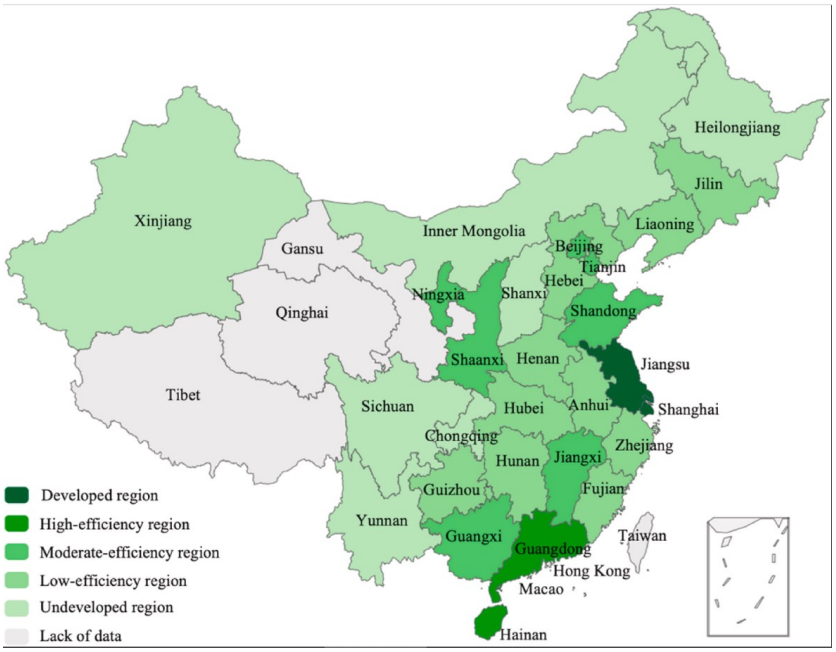

Figure 5 The efficiency of green building development in different provinces in China from 2008 to 2015. (Chen, Chan, Darko, & Gao, 2022)

There are large differences in the spatial distribution of green buildings in China, both from a regional and provincial perspective, and the imbalance in regional development is very visible, with most of the areas with a high number of green building projects concentrated on the eastern coast and in areas with better economic, policy, and other environments.

4.2.2 Existing Problems of Green Building Development

After understanding the current situation of green building development in China, the problems are analyzed by looking at the policy, standard system, market, and technology level. Figure 7 shows the Existing Problems of Green Building Development analysis process.

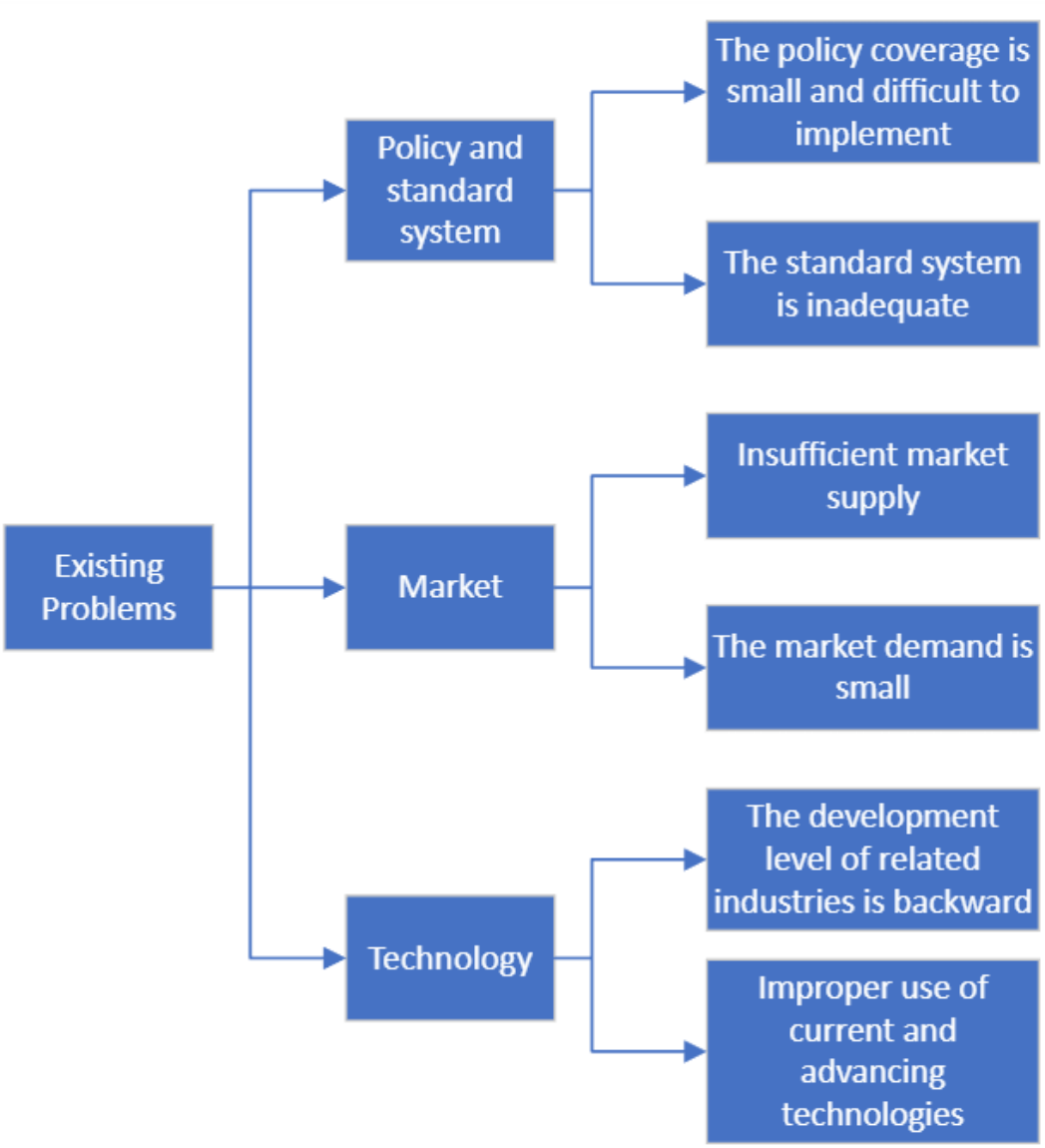

Figure 6 The Existing Problems of Green Building Development analysis process

1. Policy and standard system need to be improved.
    a. The policy coverage is small and difficult to implement.

Although the number of published green building policies in China is gradually increasing, there are gaps in the aspects of applicable laws and regulations and incentive policies. Most of the policies issued in Chongqing, Guangdong, Jiangsu, and other provinces and cities only put forward the development goals of green buildings, and do not stipulate specific practices on how to promote their development, which makes it difficult to implement the policies. Moreover, the development level of relevant regulations and policies in China's provinces

and cities also varies greatly at present. By 2022, Beijing, Hebei, Shandong, and Henan currently account for more than half of the number of relevant regulations and policies issued nationwide. In contrast, other provinces and cities are relatively behind in the research and development of relevant regulations and policies. All these factors have affected the further development of green buildings in China. (Wei, Chuan, Hao, & Hongjun, 2022)

b. The standard system is inadequate.

China's green building standards are still mainly evaluation standards, and a standard system to meet the needs of different stages of construction projects has not yet been established up to this date, to the best of the author's knowledge. First, there are no green building construction standards in place currently, and construction units are unable to generate accurate estimates, government investment projects are particularly troublesome in this regard. Second, in the planning and design stage, the Ministry of Housing and Urban-Rural Development issued the industry standard "Green Design Code for Civil Buildings" in 2010, but the code was prepared according to the 2006 version of "Green Building Evaluation Standards" and has not been updated and revised (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2020). Some localities have issued green building design standards, but they mainly aim at promoting the mandatory promotion of low-star projects, without considering the construction needs of high-star projects (Wei, Chuan, Hao, & Hongjun, 2022). Third, there are no relevant standards that can be used to guide green building construction organization, process supervision, and complete acceptance (Wei, Chuan, Hao, & Hongjun, 2022). This results in uneven construction quality and insufficient implementation of relevant technical requirements, which seriously affects the quality of green building construction. Fourth, there is no standard for guiding the operation of green buildings in the operation management stage. This results in many sustainable technical measures not achieving actual results in the operation stage. For example, it is found through research that technologies such as non-traditional water sources, renewable energy, air-conditioning autonomous regulation, rainwater harvesting and utilization, and garbage classification and collection do not run continuously in the

operation process due to poor maintenance and insufficient supporting facilities (Haifeng, 2017).

2. Market supply and demand have not been developed sufficiently, therefore market cultivation is not sufficient.
    a. Insufficient market supply.

Due to the high costs of green building construction and the long investment recovery period, construction companies are less interested in specializing in green building. As a result, green buildings are still relatively expensive and have a small market, and enterprises are not inclined to borrow the corresponding funds to finance such buildings. Although some provinces and cities have introduced support policies such as land security, volume ratio incentives, and financial subsidies, these are still not enough to offset the additional cost of building green buildings. As a result, construction companies are less motivated to invest, resulting in a serious shortage of market supply. From the perspective of design, construction, and operation management units, since green buildings have high requirements for design, construction, and operation management, the current level of most design, construction, and operation management units does not meet the corresponding requirements, which in turn affects their enthusiasm to participate. (Qiao, Dong, & Ju, 2022)

    b. The market demand is small.

On the one hand, the public lacks access to green buildings due to insufficient awareness and promotion, which impacts market demand and hampers their further development. Some members of the public, on the other hand, have fundamental misconceptions about green buildings and do not see the need to invest additional money in them (Qiao, Dong, & Ju, 2022). The minimal market demand creates a vicious circle in which the balance between the benefits of green buildings and the additional investment they require cannot be maintained.

3. Technology is outdated and technical support is lacking.
    a. The development level of related industries is backward.

At present, there is a gap between the quality and performance of domestic building energy-saving materials, products, and equipment and international standards, resulting in the need to import many materials, products, and equipment at high prices, which further affects their market development. China suffers from the following issues: First, there is a low level of research and development of related technological innovation, and the government, enterprises, and scientific research units do not conduct enough research and do not provide adequate technical support for its development. Secondly, the low level of technological innovation and research, the transformation and upgrading of related enterprises, and the insufficient guarantee of policies and standards have resulted in uneven quality and performance of energy-saving materials, products, and equipment, which in turn has affected the healthy and efficient development of green buildings. (Li, 2021)

b. Improper use of current and advancing technologies.

Many locations in China are actively working to produce green buildings, and some of these projects are using some of the advanced technology in China, if not the world, with extraordinarily high energy efficiency, boasting energy savings rates of more than 80%. However, upon further investigation, most of these energy saving rate values are simply computed values, and very few cases of actual measured operating energy usage are now accessible, and the only actual results available are not adequate. This demonstrates that the realization of green buildings must not rely exclusively on the introduction of technology and technology stacking. As a result, to realize the benefits of green buildings, more attention should be paid to understanding the concept as well as scientific design, construction, and operation through the selection of appropriate technical measures, so that the energy saving, and comfort benefits of green buildings can be realized. (Xin, 2019)

5 Internal factors for Improving Green Building Sustainability

During the life cycle of green buildings, it is critical to design energy-efficient and environmentally friendly buildings from an environmental perspective, to use resources rationally, and to reduce the negative impacts on the environment. This chapter explains how to ensure the sustainability of green buildings in the design, construction, and demolition stages.

5.1 Design phase

Implementing green buildings requires first optimizing the overall scheme. This is followed by considering the overall requirements in the planning and design stages provide the basic conditions for the needs of green buildings. The choice of different aspects will have an impact on the building as a whole and is broadly divided into three aspects: the choice of building materials, the application of renewable energy, and the application of building technology.

5.1.1 Building materials

In the Fourteenth Five-Year Plan of the National Economic and Social Development of the People's Republic of China and the Outline of Vision 2035, it is proposed to support places with conditions, key industries, and key enterprises to take the lead in reaching peak carbon emissions, and more vigorous policies and measures can be taken to strive for carbon dioxide emissions to peak by 2030 and strive to achieve carbon neutrality by 2060 (China Cement Network Information Center, 2021). Green building materials should be studied more thoroughly because building materials account for a relatively large share of carbon emissions.

4. Structural engineering materials
    a. Concrete material

Smart concrete materials, lightweight concrete materials, and low-strength concrete materials are the three types of new concrete materials. Smart concrete materials often encompass a wide range of concrete materials, including carbon fiber, temperature self-control, fiber optic sensing, and green ecology. Smart concrete components are primarily utilized to improve the strength and crack resistance of concrete and are critical in enhancing building quality. Lightweight concrete materials are low-cost, energy-efficient, and environmentally friendly. This type of material obtains the needed foam using a foaming machine and then mixes the cement with the foam to generate a concrete material with many pores. This minimizes the quantity of cement used while also reducing carbon emissions. Furthermore, the lightweight concrete material has enhanced insulating qualities due to its high number of pores and low self-weight. This simplifies the construction of high-rise buildings and has a substantial impact on the building's overall load-bearing capability. (Sha & Yang, 2021)

b. Green Cementitious Composites

According to estimates, conventional cementitious composites emit the same amount of CO_2, as well as other harmful gases and large amounts of dust for every 1t of cement clinker produced (China Cement Network Information Center, 2021).

Green cementitious composites are a new type of sustainable building material. Green cementitious composites research is currently organized into two major categories:

1) Aggregate substitution; coarse aggregates include recycled aggregates, waste glass, recycled rubber (RCR), and so on; fine aggregates include recycled fine aggregates (RFA), waste CRT glass, RCR, copper slag, steel slag, and so on.

2) Cementitious Material Substitution: Cementitious material substitution is classified into new forms of cement, such as alkali-stimulated cementitious materials, LC3 cement, nanomaterial-doped cement, rubber cement, barium sulfate cement, and so on. It can also be blended with external admixtures containing volcanic ash activity, such as slag, fly ash, expanded perlite, silica fume, rice husk ash, and so on. When compared to regular cementitious composites, the benefits include not only reduced resource consumption and

sustainable development but also environmental protection and improved safety and comfort in human living environments. The design and usage of green cementitious composites is an essential direction for the future development of the construction industry in terms of national level, environmental protection, and economic development. (Jingjie, 2018)

c. Green steel

The steel industry currently produces 7% of the world's CO2 emissions. However, green steel eliminates the need for heating, which effectively saves electricity and energy. As technology advances, Swedish Steel plans to launch the world's first 'green steel' in 2021, replacing the coal traditionally used in steel production with fossil-free electricity and hydrogen. (Bäcklin, 2021).

The widespread lack of country-specific technology and infrastructure roadmaps for industrial GHG neutrality today adds to the uncertainty and worries of businesses, industry groups, and labor unions in adopting or supporting these technologies. Policymakers, such as steel producers, labor unions, and regional development organizations, should push institutions and energy infrastructure operators to foster technological progress in inland steel industrial clusters (e.g., those in western Germany or southern Belgium). Such support could hasten the vertical integration of production on-site, preserving employment in some regions and boosting overall production energy efficiency. Steel businesses are already involved in the process: European steel companies and the European steel organization Eurofer are creating their vision for greenhouse gas-neutral steel production. (Schneider, 2022).

5. Green decorative materials

Most of the traditional decorative materials (Latex paint, plywood, wall powder, etc.) contain harmful substances (formaldehyde, benzene, radon, etc.) that are harmful to human health. Whereas green decorative materials do not contain these types of substances, are friendly to the environment and no irritating smell. Green decorative material can protect the natural environment to a certain extent and reduce pollution.

With the development of science and technology, many new technologies are applied to the environmental protection of green decorative materials, to improve comfort, and reduce energy consumption and emissions. Currently, the most popular green decorative materials are photocatalytic materials, environmental protection glass decorative materials, soft film ceiling decorative materials, artificial fiber carpet decorative materials, recyclable decorative materials, etc. (Minfang, 2020)

5.1.2 The application of renewable energy

Green buildings should effectively reduce energy consumption throughout their life cycle; renewable energy can not only replace traditional energy, reduce pollutant emissions, and protect the ecological environment, but it also has the significance of sustainable development. The use of renewable energy technology in green buildings primarily entails solar energy, geothermal energy, wind energy, biogas, and so on. This section discusses the application of these four types of renewable energy to green buildings.

1. Solar energy

Solar energy is an inexhaustible source of renewable energy, as solar energy use is the most widely used renewable energy, and one of the most efficient technologies. At present, in the field of construction, there are two main forms of solar energy utilization, namely: light-thermal utilization and light-electric utilization. The main technologies related to solar energy utilization are solar power generation, solar heating/cooling, solar hot water, solar green lighting, etc. Photo-thermal technology can be interpreted as a passive use of solar energy, such as heating a home with the sun's rays through the strategic placement of windows and the use of heat-absorbing surfaces, where the windows allow energy to enter, and the absorbed heat reduces the need for heating in the cold winter months. With the shortage of fossil energy, light-electric technology is becoming increasingly important, and this technology can solve the problem of lack of power sources. Although the upfront installation cost of such systems is high, in the long run, it can save energy costs and help reduce greenhouse gas emissions from non-renewable sources such as fossil fuels (Yutong, Lan, Siyan, Wenfeng, & Jintao, 2021).

2. Geothermal energy

One of the most abundant nontraditional sources of underground energy is geothermal energy. This energy comes from molten rock within the earth and exists in the form of heat, and its application is mainly in ground source heat pump systems. In large public buildings, geothermal is mainly used for cooling in summer and heating in winter. Geothermal has the advantage of being temperature stable and green, and compared to traditional energy sources, ground source heat pump technology is one of the most energy efficient technologies. (Alice, 2019)

In terms of form, ground source heat pump systems can be divided into surface water ground source heat pumps, groundwater ground source heat pumps, and buried pipe ground source heat pumps. Ground source heat pump systems are mainly composed of heat pump hosts, circulating water pumps, buried heat exchange pipes, buried pipe vacuum exhaust pressure setting devices, water manifold, buried pipe integrated water processor, and so on. (Alice, 2019)

3. Wind energy

In green buildings, the use of wind energy is mainly in the field of wind power generation. The energy of wind energy depends mainly on the speed and strength of the wind. Wind power generation in coastal islands, grasslands, and mountains has a broader prospect and scope than in plain areas where energy is abundant and coal fire power is easily transported. For example, the use of wind power in world is more common in the high-altitude northwest plateau and vast grassland areas. The development of wind energy resources mainly relies on vast land and sea wind farms. Wind energy is a clean energy source with the advantages of wide distribution and no pollution, but wind energy is affected by regional climate and air velocity and is unstable. With the continuous innovation of wind power generation technology, wind energy has become an important part of renewable energy utilization. The application of wind energy in green buildings is mainly reflected in wind power generation, especially in the green building complex is more widely used. With the increasing shortage of land in cities, the volume ratio of buildings gradually increases, and the spacing between

buildings becomes smaller and smaller, resulting in the weak utilization of wind energy near the ground. To solve this problem, wind power generation equipment can be installed on the top floors of buildings to provide electricity for green building complexes. In addition, in areas with high wind speed, the night lighting of cities can use wind energy, relying on turbine generators to store part of the wind energy during the day and releasing the stored energy at night, which can effectively improve the utilization rate of wind energy. (Yutong, Lan, Siyan, Wenfeng, & Jintao, 2021)

4. Biogas

Biogas refers to the fermentation of organic matter under certain adapted conditions: temperature (8 °C to 55 °C), pH (pH 6.8 to 7.6), to produce the combustible gas methane (CH_4), which is mainly used in most rural areas for power generation, heating, etc. There are various forms of domestic biogas digesters, but they can generally be divided into four categories: water-pressure digesters, floating-cover digesters, semi-plastic digesters, and tank-type digesters (Baidu Encyclopedia, 2021). The promotion of biogas not only relieves the pressure on the environment but also increases the income of the households who build them as well as maintains the local ecological balance. Currently, biogas development and promotion are low in rural China, especially in more poor areas. Most developed countries have adopted policy incentives as the driving force for the biogas power generation industry. These include strengthening scientific research investment, financial subsidies, price incentives, tax exemptions, quota systems, etc. China's development of the biogas power generation industry can learn from these valuable experiences. (Yutong, Lan, Siyan, Wenfeng, & Jintao, 2021)

5.1.3 The application of building technology

Because energy use in owner-occupied houses and commercial buildings accounts for a large share of the total global energy, the rational use of sustainable building technologies can save energy and avoid energy waste and is an indispensable part of green building design. To achieve these goals, the concepts of smart energy systems and smart automation systems

have emerged. Together they are well placed to save energy while automating and improving the livability of buildings.

1. HVAC (heating, ventilation, and air conditioning)

Buildings use about half of their energy for heating, ventilation, and air conditioning (HVAC). HVAC systems include water-cooled screw chillers with high-performance factors and environmentally friendly refrigerants. Air handling units, cooling towers, pumps, jet fans with adjustable frequency drives are regulated by a centralized IBM with variable air volumes installed in designated areas. The air handling units are connected to heat recovery units to reduce the cooling load on the chillers. To obtain better indoor air quality, a demand-controlled ventilation system with CO2 sensors was necessary. The main goal of the HVAC system is to reduce the building's electricity consumption from the grid. (Wikipedia, 2022)

2. Energy-saving technologies for windows and doors

The green construction technology in windows and doors is reflected in the design of the window and door structure, and the use of new energy-saving window and door materials can bring the energy-saving performance of windows and doors into full play. In the case of high-performance aluminum alloy doors and windows, the setting of inward opening and inverted opening method can effectively ensure good ventilation and can also strengthen the energy-saving effect and waterproof performance of windows and doors. The implementation of the window and door design work needs to clarify the characteristics of the building structure, to ensure the rationality of window and door area planning work. After selecting the materials for window and door construction, construction workers need to check the shape of the windows and doors, glass strips, and steel lining assembly, and only after ensuring that the indicators meet the construction needs of the project, can the installation of windows and doors be carried out to ensure the rationality of window and door design. (ENERGY.GOV, 2022)

3. Roof energy-saving technology

The impact of roofs on energy is often overlooked, but the impact can be huge. In winter, inadequate, or damaged roof insulation makes it easy to lose heat, while in summer, the heat gained through the roof not only increases the cooling load but also increases the electricity demand. Here are two examples of roofing technologies: insulated roofing and cold roofing.

Insulated roofing technology brings out the insulation properties of the roof, and the use of this technology requires the completion of the pouring operation at the construction site. For example, materials such as rigid polyurethane foam or foam concrete are used. This series of insulation measures can fully play a role in strengthening the insulation effect of the roof so that the loss of indoor temperature can be controlled within a reasonable range to protect the indoor temperature. (COOLDEC, 2022)

Cold roofing is a sustainable green building technology designed to reflect heat and sunlight. It helps to maintain the building at standard room temperature to a large extent by suppressing heat absorption and heat emission. In short, they reflect more sunlight than ordinary tile roofs and prevent warm and cold indoor air from escaping from the roof (Feng, Saliari, Gao, & Santamouris, 2022).

4. Rainwater recycling system

The complete building rainwater recycling system mainly includes an initial rainwater abandonment device, flower bed infiltration and purification device, filter, rainwater collection module, collection well, pumping pipe, water pump, etc. Rainwater flows through the roof into the initial rainwater disposal device, and after filtering, the disposed of rainwater is discharged through the sewage pipe. A small amount of rainwater is absorbed by the vegetation in the flower bed, and the remaining rainwater flows into the water collection well through the infiltration pipe in the device. The infiltration pipe is connected to a filter at the bottom of the catchment well, which is covered with uniform circular holes. At the same time, the rainwater naturally infiltrates through the vegetation of the low potential green space, and after the assembled rainwater collection module, the larger impurities mixed in the rainwater will be excluded from the outside world and the rainwater

will be collected. The collected rainwater flows through the inlet pipe into the filter at the bottom of the water collection well, and then enters the water collection well after filtering. There is a pumping pipe in the collection well, and the pumping pipe will pump the rainwater collected in the collection well into the water tank through the action of the pump, and the rainwater in the water tank can be used for washing clothes, flushing toilets, and other purposes after repeated infiltration and filtration. (Anhui Gezhi Green Building Design Co., Ltd., 2019)

5.2 Construction phase

1. Apply to construction site layout

The preparation work in the pre-construction stage of the construction project is the construction site layout, and the success of this work directly determines the development of the work in the later stage. Therefore, to effectively ensure the quality of construction site layout, it is necessary to use green construction technology, namely: (1) relevant engineers need to conduct a detailed survey of the actual situation of the construction site, and draw the actual situation of the project scientifically, on this basis, should also present the survey and planning results in the engineering construction drawings, and strictly follow the scientific principle to carry out the fenced area in an orderly manner The work of the fenced area, road planning and the division of the temporary site;(2) based on the comprehensive grasp of the information of the project, it is necessary to integrate the concept of skills into it, to give full play to the role of the resources, in the process of carrying out the work, attention should be paid to the choice of the location of material storage, as close as possible to the construction site, so that not only can effectively alleviate the problems of the construction site traffic, but also save transportation costs. (Luodan, 2019)

2. Environmental protection technology

To comply with the concept of sustainable development, the construction industry needs to use environmental protection technology, which can play a very positive role in the production and life of human society and the ecological environment. For example, to avoid

dust problems as much as possible, we need to effectively implement watering and covering of earthworks. For steel construction, the use of foam panels can reduce noise. The water used in construction projects needs to be ensured to be fully used before it can be excluded, otherwise, it will bring serious pollution to water resources and destroy the ecological balance. (Luodan, 2019)

3. Green construction management

The implementation of the green building construction concept should also carry out green construction management work, to give full play to the role of green construction technology and ensure that the use of green construction technology can meet the green construction standards and requirements. Points to note: (1) ensure that the engineering personnel have the awareness of green energy saving, to effectively implement the construction preparation work;(2) ensure that the materials used in the construction process of engineering projects have the characteristics of environmental protection and energy saving and realize the recycling of materials to avoid the phenomenon of material waste. (Luodan, 2019)

5.3 Demolition phase

Green buildings promote the use of recycled materials, and the "Green Building Evaluation Standards" gives recyclable materials a high extra point value (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2020). Building materials are diverse and widely used. These include inorganic materials such as natural stone, concrete, building steel, fired earth products, architectural glass, and alloys, as well as organic materials such as wood, plastic, and asphalt. Construction waste is transported, landfilled, incinerated, and recycled during the demolition phase of the building. Building deconstruction, material classification, material collection, and recycling of construction material resources are necessary to achieve multiple recycling of construction material resources. The reason for this is that construction materials cannot be reused. To achieve multiple recycling of construction material resources, new materials that are like or completely different from the old ones are created by changing their material forms.

1. Wooden building materials

Most of the wood dismantled from old buildings can be reused after simple physical processing by lathes or workers (e.g., pulling out nails, removing rotten parts, reshaping, etc.). If the recycling of materials is carried out, it is possible to produce fiberboard or paper, etc. If the nature of the dismantled wood is such that it can no longer participate in the internal circulation of the material system, wood chips and shredded wood, which have been determined to be free of harmful substances such as preservatives, fire retardants, and paints, can be used as fuel or compost. Waste wood can be mixed with clay and cement to produce a special type of concrete. This concrete has the advantages of light material and low thermal conductivity compared to ordinary concrete and can be used as an adiabatic material. As the admixture of waste wood reduces the capillary effect of the composite material, both the durability and thermal conductivity of this composite material are less affected by humidity. (Yulong, 2018)

2. Concrete materials

Waste concrete blocks are crushed, cleaned, and size-graded in a series of concrete recycling techniques, then mixed in a specific size ratio to form recycled aggregates, which are used to replace natural aggregates in part or in whole to form reinforced concrete for civil engineering construction such as roads, bridges, and buildings. In addition, there is a relatively small amount of waste concrete after crushing and screening, into the wire cage, instead of stone for hydraulic engineering or landscape engineering, this achieved good results. (Yulong, 2018)

3. Steel materials

Unwanted steel products are recycled as a valuable commodity and then melted down by the scrap processing industry to become commercial products. Steel sections and bars from building dismantling are cut to size, mainly by cutting machines, and sifted through magnets to become large scrap. The large scrap contains fewer impurities, while the reinforcing bars with concrete on the surface are more difficult to process in an electric furnace. The recycled steel material is less stable due to the various impurities mixed in. Hence, the recycling of

scrap metal requires specific instruments to determine its composition, ensuring that many complex and diverse alloy types and material quality can be analyzed quickly and accurately on site. (Tao, 2015)

4. Masonry

The mineral composition and form of waste brickwork remain largely stable, making it valuable for further use. After the simple mechanical dismantling of masonry buildings, the blocks are manually sorted and the mortar residue removed, and then reused for less demanding wall masonry, which is the most common form of reuse. It can be used as a coarse aggregate for heat-resistant concrete, which does not crack on the surface after being burnt at high temperatures. In addition, waste brickwork can also be pulverized and used as raw material for no-pour masonry cement or as raw material for recycled brickwork. (Tao, 2015)

5. Asphalt

Recycled asphalt roofing waste can be used as cold mix material for producing hot mix asphalt and filling potholes, thus reducing the use of pure asphalt and aggregates in asphalt, while the fiber material contained in asphalt roofing helps to improve the performance of hot mix asphalt and reduce pavement deformation and cracking. In general, the rate of incorporation of asphalt roofing waste in hot mix asphalt pavements for high-grade roads is 5%, while the rate of incorporation of asphalt roofing waste in hot mix asphalt pavements for low-grade roads can be 10% to 15% (Luochun & Youcai, 2004).

6 External factors for Improving Green Building Sustainability

With the rising demand for energy-efficient buildings, many countries are actively exploring and studying buildings with higher energy-saving standards. Germany and the United States are at the forefront of promoting the development of energy-efficient buildings in the world, and their corresponding practical experience is also a reference for all countries. (Yu, Li, & Xianchao, 2020) Domestically, Hebei Province has been actively exploring suitable energy-

efficient buildings with its regional climatic advantages, and especially Hebei Province has achieved good implementation results in promoting the development of green buildings. Therefore, it is important to summarize the practical experience of promoting energy-efficient building development at home and abroad and to summarize the useful inspiration for promoting the sustainable development of green buildings in China.

6.1 Policy aspects

The sustainable development of green building is inseparable from policy protection and support. Looking at the experience of Germany, the United States, and Hebei Province in the development of energy-efficient buildings, the policy should, firstly, strengthen the construction of relevant legislations and regulations and clarify the development goals of energy-efficient buildings; secondly, it should improve the supporting incentive policies and pay attention to the effect of policy incentives; thirdly, it should increase the publicity and promotion efforts to enhance the recognition of buildings.

1. Strengthen the construction of legislation and regulations, and clarify the development goals

Combined with the relevant development experience of Germany, the United States, and Hebei Province, comprehensive laws and regulations and clear development goals have played an important role in promoting the development of energy-efficient buildings. Germany has introduced laws and regulations that are compatible with the development of green buildings. The comprehensive laws and regulations have created a good legal environment for the development of passive buildings in Germany and ensured their healthy and orderly development of green buildings in Germany. (Yanfeng, 2020) To promote the development of green buildings, the U.S. government has formulated clear development goals for green buildings, and at the same time, each state government has also formulated corresponding development goals to the actual situation, and the clear development goals also provide a clear direction for the development of green buildings. (Yanjie, Shicong, Wei, & Connelly, 2020)

2. Improve supporting incentive policies and pay attention to the effect of policy incentives

Through the analysis of domestic and international experience in the development of energy-efficient buildings, government incentives play an important role in promoting the efficient development of energy-efficient buildings, while the formulation of incentive policies should focus on combining the actual situation of the region and the incentive effect. The main feature of Germany's passive house incentive policy is that it benefits a wide range of companies, individuals, and households involved in the construction of passive houses with the support of KfW bank, and to ensure the effectiveness of the incentive policy, Germany applies a graded subsidy according to the energy efficiency standards of the building project. (Yanfeng, 2020) The United States has established corresponding incentive policies mainly from the two aspects of energy supply and individual projects. On the one hand, by increasing the incentives on the energy supply side, the United States promotes the market-oriented development of renewable energy, effectively reducing the overall cost of zero-energy buildings, thereby improving the market competitiveness of zero-energy buildings. On the other hand, the FAR and floor area incentives are adopted for individual projects to increase the enthusiasm of relevant entities to participate and promote the development of zero-energy buildings. (Yanjie, Shicong, Wei, & Connelly, 2020) In addition, China's Hebei Province has accumulated some experience in developing green building incentive policies. Hebei Province has effectively promoted the development of green buildings in the province by establishing diversified incentive policies, such as financial rewards, floor area ratio incentives, guaranteeing land supply, simplifying the approval process, and providing technical support. (Hebei Provincial Department of Housing and Urban-Rural Development, 2020)

3. Increase the publicity and promotion efforts to enhance the recognition of the building

Green building has been developed in China for a relatively short time, and the public and enterprises know less about them and even have wrong perceptions about them, which seriously affects the market recognition of green building. To further enhance the market

recognition of green buildings, the government should increase the publicity and promotion to deepen the public and enterprises' understanding of green buildings. Drawing on the advanced experience of green building publicity in Hebei Province, it can establish an all-round publicity pattern to promote green building advantages, advanced technologies, and advanced concepts, and effectively deepen the understanding of the public, practitioners, and enterprises, to enhance the enthusiasm of relevant subjects to participate in green building construction. (Hebei Provincial Department of Housing and Urban-Rural Development, 2020)

6.2 Market aspects

According to the development experience of green energy-saving buildings at home and abroad, the market aspect is to pay attention to the market-oriented operation and give full play to the autonomy of market regulation; secondly, to accelerate the development of related industries and enhance the industrial support capacity.

1. Pay attention to market-oriented operation, play the role of market autonomy regulation

Green building sustainable development, in addition to the need to pay attention to policy, technology, and other support, should also pay attention to its market-oriented operation, and allow for complete market regulation autonomy. Green building market operation, in the United States has formed its unique market operation. On the one hand, the U.S. Department of Energy and the U.S. HVAC Society respectively set the goals of the U.S. federal government for new and renovated buildings, new zero-energy residential buildings, and commercial buildings market operation, providing a clear goal for the development of the zero-energy building market. On the other hand, by promoting the market-oriented development of renewable energy, the total cost of zero-energy buildings can be effectively controlled, thus enhancing the competitiveness of the zero-energy building market. The use of renewable energy market-oriented development to drive the development of the zero-energy building market is the most important feature of the development of the U.S. zero-energy building market. (Yu, Li, & Xianchao, 2020) Therefore, to promote the development

of green buildings, importance should be attached not only to the promoting role of the government but also to the regulating role of the market. By promoting the market-oriented development of energy-saving materials, products, and energy, we can control the construction costs, thus enhancing the competitiveness of the construction market.

2. Accelerate the development of related industries and enhance industrial support capacity

The sustainable development of green building requires the support of related industries. Mature industrial development can not only control the cost of related materials and products through industrial planning and development but also promote industrial transformation and upgrading to ensure the quality of building materials and products. Germany has formed a mature industrial chain in the process of promoting the development of the passive house. The mature industry chain provides strong industrial support for the development of passive houses in Germany, and effectively promotes the efficient development of passive houses in the country. With the financial support of KfW bank, the German industry chain has continued to carry out technology and product innovation research and development and has continuously adapted to the development needs of passive houses. At the same time, Germany constantly improves the relevant standards and specifications and promotes the standardization of building material design and production, which effectively enhances the development of passive house development. (Yanfeng, 2020) The rapid development of green buildings in Hebei Province is also inseparable from the support of related industries. By releasing corresponding industrial plans, optimizing the industrial layout, enhancing industrial innovation and research and development capabilities, and promoting the scale development and quality improvement of building materials and products, the industrial foundation has been consolidated to ensure the healthy and sustainable development of green building in Hebei Province. (Hebei Provincial Department of Housing and Urban-Rural Development, 2020)

6.3 Technical aspects

The development of green buildings in the world is inextricably linked to technology support: the first is to concentrate on methods of technology implementation and enhance the coordination and application of technology, and the second is to enhance the level of technological innovation and research and development.

1. Pay attention to the effect of technology implementation and enhance the ability of technology integration and application

The choice of green building technology should consider energy efficiency and economy, as well as the climatic conditions, local characteristics, and resource environment of the region where the building is located. To explore the development of zero-energy buildings, the United States has developed a technology application model of "passive priority + active optimization + renewable energy supplementation", which uses passive technology to reduce baseline energy consumption levels of buildings, active technology to enhance comfort levels, and renewable energy to supplement energy use. In terms of renewable energy use, the United States has taken photovoltaic power generation as the most important strategy to promote the development of photovoltaic systems, to control the overall cost of zero-energy buildings, and to encourage zero-energy building development, considering the current state of renewable energy development. (Yu, Li, & Xianchao, 2020) To effectively control building costs and improve building energy efficiency, it is crucial to adopt appropriate technical measures in conjunction with regional climatic conditions and resource conditions.

2. Enhance the level of technological innovation and research, and strong technical support

To achieve green building, high-tech materials and advanced technologies are necessary. In China, the quality and performance of relevant materials and products cannot meet the demand for green buildings and must be imported at a high cost, increasing the cost of green buildings in China, and affecting their sustainable development. Therefore, the

government should invest more in scientific research and further seek to develop green buildings through technological innovation. The development of energy-efficient buildings has been supported through continuous technological innovation and research in Germany, the United States, and Hebei Province to promote the good and rapid development of energy-efficient buildings. With the support of KfW bank, Germany continues to develop new technologies and materials for innovation (Yanfeng, 2020). As a part of its efforts to achieve zero energy consumption and control the total cost of construction, the United States actively explores the use of renewable energy sources in the zero-energy building to achieve zero energy consumption in buildings (Yu, Li, & Xianchao, 2020). In contrast, Hebei Province has adopted the development idea of industry-university-research-application, actively organizing universities, scientific research institutions, enterprises, and government functions for the innovative research and development, production, and promotion of new technologies and products (Hebei Provincial Department of Housing and Urban-Rural Development, 2020).

6.4 Management aspects

On the one hand, the management should improve the localized standard specifications; on the other hand, it should accelerate the establishment of third-party certification institutions and improve the system of building certification marking.

1. Strengthen the construction of localized standards and norms, and consolidate the standard support

There are significant differences between green building and existing standards and norms in the design, construction, monitoring, materials, products, operation, and maintenance of various aspects. Therefore, to encourage the effective development of green buildings in various locations, it is crucial to develop the appropriate design, construction, and acceptance standards by local characteristics. Germany has gradually improved its passive house standards while considering the local climate. Design standards, construction standards, and evaluation standards all serve as solid benchmarks for the advancement of the passive house. Additionally, Germany has gradually improved not only the standards for

energy-efficient buildings but also the standards and norms related to the design and manufacture of building products, which has aided in the standardized growth of related industries. (Yanfeng, 2020) As a result, to encourage the development of green buildings in a sustainable manner, appropriate and implementable standards, and norms should be developed by thoroughly integrating the climatic traits and building types of each region, providing a framework for the relevant green building participants.

2. Establish a third-party certification body and improve the building certification and labeling system

The development of a green building certification mark system should not only concentrate on the building's ability to save energy, but also on the certification of building products, building materials, design, and construction technology. The implementation of green building-related materials, products, and technologies will be encouraged by the creation of an all-encompassing certification and marking system as well as by the practical strengthening of certification of building materials, products, design, construction, and operation. Additionally, consideration of the function of independent certifying bodies should be a key component of the development of the building certification and marking system. The Building Energy Efficiency Regulation, which supports the German passive house certification and labeling system, evaluates buildings based on three factors: energy consumption, energy demand, and recommendations for enhancing energy efficiency. Buildings that meet the standards are awarded "energy-saving certificates," while those that cannot receive "energy certificates" by the regulations are penalized (Baidu Encyclopedia, 2021). Buildings that are not eligible for an energy certificate are also fined correspondingly. The German Passive House Institute, which has emerged as the world's leading certification body for passive homes and passive energy-saving systems, currently handles most of the certification of passive houses in Germany.

6.5 Social aspects

The government's focus on the development of green building architecture should be effectively increased to promote efficient building development while focusing on raising

public awareness of energy conservation and bolstering the public foundation. This can be done by analyzing the experience of other countries in the development of green buildings.

3. Enhance the importance of the government and promote the development of efficient buildings

The importance of the government is strongly tied to the growth of green buildings, as seen by the German passive house, American zero energy, and Chinese green building movements. With the assistance of KfW, the German government actively develops pertinent legislation and regulations to encourage the development of passive houses and actively adopts effective incentive schemes, creating favorable conditions for the growth of passive houses (Yanfeng, 2020). Each state and the federal government actively develop its own zero-energy development goals based on the U.S. federal government's explicit zero-energy development goals, which are based on its national conditions. The U.S. federal government has also developed the "energy supply side + individual projects" incentive policy by the state of the zero-energy building market's development, which has significantly increased the market's competitiveness (Office of the Governor State of Oregon, 2017). Considering its favorable climate characteristics, the government of Hebei Province, on the other hand, has been enhancing its green building incentive policies and fostering the growth of related companies. To stimulate the construction of energy-efficient buildings, it is important to increase government attention at all levels and to take proactive actions while considering the specific circumstances of each region. (Hebei Provincial Department of Housing and Urban-Rural Development, 2020)

4. Raise public awareness of energy conservation and strengthen the public foundation

Since the public will ultimately be using a green building, public recognition will have a significant impact on the development of the industry. Additionally, societal awareness of green construction is directly correlated with individual energy-saving awareness. Therefore, raising public awareness of energy saving and laying a solid public foundation for green buildings should be the main goals of campaigns encouraging the sustainable growth of green buildings. To increase public awareness of energy conservation, we need not only to

strengthen the promotion of energy conservation ideas but also work to change people's attitudes and behaviors. In Germany, legislation and regulations on energy conservation and environmental preservation have been developed, in addition to public education campaigns. Environmental police have also been established to efficiently control public conduct, creating the groundwork for the growth of passive houses in the country. (Yanfeng, 2020) In Hebei Province, the concept of green building energy conservation and related policies have been actively promoted through the distribution of pamphlets, the creation of publicity pictorials, and the establishment of public WeChat numbers, among other methods. (Hebei Provincial Department of Housing and Urban-Rural Development, 2020)

7 Analysis and discussion

Combined with the above analysis of the internal and external factors affecting the development of green buildings in China, the five major directions of policy, market, technology, management, and social consciousness are summarized to suggest countermeasures to promote the sustainable development of green buildings in China.

7.1 Policy aspects

1. Strengthen laws and regulations

Based on the results of the extraction of key influencing factors and the inspiration derived from the experience of energy-efficient building development at home and abroad, effective laws and regulations can provide a favorable and stable development environment for the healthy development of green buildings and play an instrumental role in ensuring the sustainability of green buildings. To strengthen the construction of relevant laws and regulations, attention should be paid to combining the characteristics of green buildings and existing laws and regulations. This will enable effective ensuring that newly introduced or revised laws and regulations meet the current and future development needs of green buildings. In addition, attention should be paid to strengthening the construction of laws and regulations related to public energy use, to restrain the public's energy use behavior.

2. Improve supporting incentive policies

Green buildings have attracted a lot of attention as a kind of energy-saving building concept. However, its strong externalities and high costs limit its sustainable development. Therefore, the government must adopt appropriate incentive policies to effectively promote its sustainable development.

a. Develop a diversified incentive policy.

At present, in the process of promoting the development of energy-efficient buildings, local governments mostly use financial subsidies, which have a certain role in promoting their development in the short term but will increase the economic pressure on the government in the long run. Therefore, when formulating incentive policies, the government should combine the current situation in the region and develop diversified incentives. These incentives include financial subsidies, matching reductions, floor area ratio incentives, provident fund incentives, tax concessions, process optimization, guaranteed land supply, and scientific and technological support. At the same time, the incentive policy should be formulated to ensure full coverage of the incentive targets. This should cover both developers and consumers, as well as design, production, construction, and operation units.

b. Formulate incentive policies according to local conditions.

Each region should develop appropriate incentive policies according to local conditions. For provinces and cities with higher development levels, the government can appropriately reduce direct economic incentives and adopt other non-economic incentives to alleviate government financial pressure while safeguarding the development of green buildings. For regions with lower development levels, the government can formulate incentive policies according to the actual needs of regional development, considering factors such as the government's financial status, the public will for green building, the difficulty of policy implementation, the difficulty of project implementation and the technical level.

3. Increase government publicity and promotion efforts

Although certain progress has been made in the development of green buildings in China, the overall level of development is still low. Therefore, it is necessary to increase the publicity and promotion of green building concepts, roles, and key technologies. This will strengthen the awareness and understanding of enterprises, practitioners, and the public of their advanced concepts and roles. This will in turn lead to their commitment to green building development.

Furthermore, the government should widen its PR channels and focus on the publicity effect. On the one hand, the government can demonstrate and promote advanced concepts, benefits, advanced technology products, typical cases, regulations, and policies of green building through special reports and exhibitions, forums, and on-site exchanges, thereby increasing its recognition among enterprises and the public. On the other hand, media tools such as radio, newspaper, television, and network can be used to increase the publicity and popularization of green building-related content. Furthermore, the government should pay attention to the actual publicity effect during the publicity and promotion process, so that businesses and the public have a comprehensive grasp of green building.

7.2 Market aspects

1. Upgrading the development of related industries

One of the major factors limiting green buildings' long-term development is their high cost. As a result, encouraging the localization and scale development of green building-related industries can effectively reduce the cost of materials and products used in them, lowering overall building costs, and enhancing building sustainability. To promote the development of the green building industry, we should first strengthen innovation and research and development of new products and technologies, as well as improve the quality of products and key technologies to compensate for the short supply of key basic materials and technical processes in the development of the green building industry, to solve the problem of reliance on imports of key materials, parts, and components at an early stage and reduce construction costs. Second, we should improve the standardization of green building product design and encourage scale development to reduce construction costs. For example, the

standardized development of green buildings should be strengthened by improving the continuous integration of green buildings and assembly buildings.

2. Enhancing the effect of the market-oriented operation

The sustainable development of green buildings should not only be promoted by the government but should also be regulated by the market. By enhancing the level of market-oriented operation of green buildings, market development can be promoted. To promote the market-oriented operation of green buildings, the reduction of construction costs and the enhancement of construction efficiency is of paramount importance. Effectively reducing the cost of construction and enhancing the level of construction efficiency is a direct impetus to support the sustainable development of green buildings. It can effectively regulate the level of market supply and demand. Among the reduction of green building costs, one should strengthen the utilization rate of local building materials and products, etc. to reduce material costs; secondly, it should focus on the quality of green building design, which should be combined with local climate characteristics and energy consumption habits, etc. Thirdly, it is reasonable to compare technologies and adopt technologies with positive benefits and short payback periods to reduce technology costs and improve the overall cost-effectiveness of the building, thus reducing the overall cost. In addition, during the building construction process, attention should be paid to the quality of technical implementation to avoid improper technical operations, which can cause rework and increase construction costs.

7.3 Technical aspects

1. Promote technological innovation and research

The development of green buildings in China is still in its infancy, and many materials, equipment, and technologies need to rely on imports, causing its slow development. To promote the sustainable development of green buildings in China, we should strengthen the capacity of independent innovation and research and development of relevant technologies in China, overcome technical problems and develop some localized, high-quality, and high-

performance materials and products. The promotion of technological innovation and research should effectively play the role of universities, scientific research institutions, and other units of research, encourage enterprises to establish independent innovation systems, and promote the development of the integration of industry, academia, research, and application.

a. Encourage universities and scientific research institutions to conduct research on green building products and technologies by increasing special scientific research investment, promoting the independent innovation and research capacity of key technologies and products, providing technical support and basic guarantee for the sustainable development of green buildings, reduce reliance on imported materials, equipment, and products, and thus effectively control construction costs.
b. Support leading enterprises to establish innovative R&D platforms and promote the innovative R&D capability of the whole industry chain of green buildings. Strengthen enterprises to jointly build technological innovation and R&D platforms that integrate R&D, pilot testing, testing, and promotion, and to overcome key technologies such as insulation, thermal insulation, waterproofing, and energy environment, to comprehensively enhance the basic innovation and R&D capacity of enterprises.
c. Combine universities, scientific research institutions, and enterprises' practical experience to promote the innovation and application of new technologies, new techniques, and new materials in green building practices, and to maximize the utility of cooperation between industry, universities, and research institutes. Through the integrated development of industry-university-research-application, the organic integration of theory and practice is effectively carried out to prevent the disconnection between technology research and development and the market. In addition, by setting up a special technical guidance agency, professional technical guidance can be provided to enterprises to solve technical problems, thus strengthening their confidence, and continuously promoting the construction of green buildings.

2. Upgrade the level of technology co-ordination and application

The core objective of green building is to achieve low energy consumption and environmental comfort in buildings. Therefore, the use of updated technologies, new products, and new techniques is sometimes necessary. However, the pursuit of using new technologies and technology stacking not only increases the overall cost of the building but may even result in increased building energy consumption and affect building comfort. Therefore, in the process of green building construction, attention should be paid to the integrated application of technology, to ensure that the requirements of the various indicators of the building are met, and to control the overall cost of the building as far as possible. To enhance the level of technical coordination and application, on the one hand, we should effectively grasp the characteristics of green buildings and clarify the conditions that should be met to achieve the various indicators of the buildings. On the other hand, appropriate technologies, materials, and products should be selected in conjunction with the regional climate and resource environment, and the relationship between achieving the goals of low energy consumption and comfort and controlling the overall cost of the building should be well balanced. To achieve the above two points, firstly, the concept of the main actors involved should be effectively changed from the pursuit of using high technology to focusing on the effect of technology implementation, to effectively achieve the goal of ultra-low energy consumption and environmental comfort in buildings; secondly, training should be provided to practitioners in design and operation, etc. The technology used in buildings is largely influenced by the design of the building. Strengthening relevant training and deepening designers' understanding of the characteristics, concepts, and design points of green buildings, can help them to better select appropriate technologies and achieve the effect of controlling the overall cost of buildings while meeting the requirements of various building indicators.

7.4 Management aspects

1. Strengthen the cultivation of talents

Fully tapping into existing human resources is an important way to alleviate the pressure of the lack of professional green building talents in China. Therefore, there is an urgent need to increase the education and training of green building practitioners and to strengthen the

professional training of practitioners in research and development, design, construction, supervision, production, operation and management, and testing.

a. Strengthen the introduction of talents.

Strengthening the introduction of talents is a convenient way to alleviate the pressure of the lack of green-building talents. On the one hand, the government and enterprises should carry out extensive recruitment of talents in conjunction with the actual situation and introduce professional talents to alleviate the pressure of talent shortage. On the other hand, the introduction of talents should be effectively safeguarded by formulating clear safeguard measures, incentive policies, and assessment mechanisms.

b. Strengthen the cultivation of talents.

We can make full use of educational resources and establish a mechanism for cultivating talents in universities. By strengthening the cooperation between the government, enterprises, and universities, and by giving corresponding support to scientific research funds, we can build a talent training base and cultivate professional talents for the development of green buildings. In addition, universities can also provide professional consulting services to enterprises by strengthening research on typical cases of green buildings. At the same time, the educational resources of universities can be used to strengthen the training of innovative talents and promote the innovative research and development of key materials, products, and technologies, to speed up the resolution of technical problems facing the sustainable development of green buildings.

c. Strengthen the training of talents for enterprises.

Enterprises in construction, design, construction, supervision, and testing should strengthen training in green building-related content. By formulating training plans and contents, enterprises can provide regular training to practitioners, for example construction enterprises can strengthen training on green building concepts, construction techniques, and construction skills to enhance the construction level of construction personnel. In addition, enterprises can also invite industry experts to share knowledge about green building,

construction experience of typical cases, the latest energy-saving materials, and key technologies to enhance the professional knowledge of practitioners.

2. Strengthen the construction of standards and specifications

The degree of perfection of standards and codes is an important sign of the maturity of a certain field of development and is an important yardstick to guarantee the quality of construction. Therefore, the promotion of the construction of green building-related standards and codes should focus on strengthening the operability of the standards and codes and strengthening the market-oriented application of the standards and codes.

a. Strengthening the operability of the standards and codes.

At present, China's green building-related technical standards and codes and evaluation standards are still not perfect. Therefore, it is important to accelerate the development of the corresponding product, design, construction, testing, and evaluation standards around the world to effectively guarantee the sustainable development of green buildings. Countries, regions, industries, and enterprises should focus on their adaptability and operability when formulating the corresponding technical codes and standards, focusing on the guiding role of prescriptive indicators, and enhancing the supporting role of operational indicators, to promote the implementation of the standards on the ground and make them adaptable to the development of green buildings. In addition, each region should also formulate standard codes that are suitable for regional development, considering climate characteristics, indoor environments, and building types, to ensure the laudability of the standard codes.

b. Strengthen the market-oriented application of the standards and specifications.

The development of relevant technical and evaluation standards should give full play to the role of market players and encourage competent industry associations and enterprises to develop technical and technologically advanced evaluation standards, of a high standard and adaptable to market development, to promote the development of green buildings to higher

standards. In addition, national, regional, industry, and enterprise standards should be formulated with coordinated planning to avoid contradictory and unreasonable provisions in national standards, local standards, industry standards, and enterprise standards, and to avoid creating obstacles to the implementation of the standards.

3. Strengthen the construction of the certification mark system

A accurate certification and labeling system can effectively promote the development of green buildings. Therefore, the certification and labeling system for relevant materials, products, building design, construction, and operation should be further improved to guarantee the quality through an all-round assessment of building energy efficiency, environment, and health, etc. In addition, third-party certification bodies should be further fostered, and the role of industry associations, societies, and consultancies should be brought into play to bring together social forces to promote the construction of the certification and labeling system and to escort the sustainable development of green buildings.

7.5 Social aspects

1. Increased attention from governments at all levels

In the whole system of sustainable development of green buildings, it is not enough to rely on the regulating role of the market itself but must rely on the guiding and supervising role of the government. Therefore, governments at all levels should pay more attention to green buildings and effectively play the role of promoting sustainable building development. On the one hand, the central government should set a good example for local governments by raising the level of concern for energy-efficient buildings and providing direction for local governments by improving relevant regulations and policies, formulating specific measures, and deepening the refinement of various provisions. On the other hand, local governments should correctly understand the characteristics of green buildings, and in areas where it is appropriate to promote green buildings, local governments should actively formulate corresponding regulations, ordinances, and policies to ensure their healthy development,

while localities should pay attention to the combination of local climatic characteristics and resource conditions to formulate practical and easy-to-operate policy measures and enhance policy enforceability.

2. Strengthen the sense of corporate social responsibility

A lack of corporate social responsibility not only increases social costs and reduces the cost-effectiveness of construction, but also affects the process of promoting energy efficiency in buildings. The lack of corporate social responsibility will not only increase the cost to society and reduce the cost-effectiveness of construction but will also affect the promotion of energy efficiency in buildings. Therefore, it is important to strengthen corporate social responsibility to promote the sustainable development of green buildings. By strengthening corporate social responsibility, it will enable companies to focus on the quality of their production, design, construction, and operation, as well as enabling them to strengthen their technological innovation and research and development, and to invest effectively in the development of building energy efficiency. For their part, enterprises can integrate social responsibility into their business activities by combining their overall development strategies, setting up special institutions, and formulating corresponding assessment standards to implement social responsibility in practice. At the same time, staff training programs are developed to cultivate their awareness of social responsibility, and corporate social responsibility reports are published to enhance the image and competitiveness of enterprises in society. For its part, the government has been promoting the motivation of enterprises to fulfill their social responsibility by formulating material and spiritual incentives. At the same time, by formulating mandatory policies and increasing disciplinary measures, enterprises are urged to effectively fulfill their social responsibilities.

3. Raise public awareness of energy efficiency

The public is the ultimate user of buildings, and their needs have an influence on the sustainable development of green buildings. Public demand is largely influenced by their awareness and knowledge of energy-efficient buildings. Therefore, raising public awareness of energy efficiency plays an important role in promoting sustainable building development.

To raise public awareness of energy efficiency, on one hand, demonstration project displays, public service announcements, media columns, and technical exchanges can be used to publicize the concept, advantages, and experience practices of building energy efficiency, thereby improving public perception of green buildings, raising public awareness of energy efficiency, and enhancing its acceptance. On the other hand, public behavior can be restrained through the introduction of mandatory energy-saving policies. Drawing on the German approach, the rate of application of energy-saving products and technologies can be increased by improving legal policies, and the behavior of the public can be regulated through the establishment of a special regulatory body.

8 Conclusion

The thesis begins by examining the characteristics and state of the development of green buildings in China. Based on this, it analyzes the state of its development now and notes that although China's green building development has made some strides in terms of policies, standards, and construction scale, there are still some issues with it. First, the pertinent standards and policies are imperfect and fall short of offering effective standards and policy protection. Second, market supply and demand are not sufficiently stimulated, and market cultivation is insufficient. Third, the applicable technology is outdated and does not offer powerful technical support.

The issue is resolved through a methodical analysis of the internal and external factors affecting the development of sustainable green buildings. To ensure the sustainable development of green buildings at various points in their life cycle, internal factors must be analyzed. To gain insight, the analysis of external factors summarizes and arranges the five aspects of policy, market, technology, management, and social awareness. It draws on the advanced experiences of Germany, the United States, and Hebei Province in promoting the development of energy-efficient buildings.

The final summary makes suggestions to encourage China's sustainable development of green buildings. To suggest appropriate countermeasures in the areas of policy, market, technology, management, and social awareness, the findings of the analysis of key

influencing factors are combined with domestic and international development experiences. These specifically include enhancing the creation of pertinent laws and regulations, creating, and improving incentive policies to support them, increasing government publicity and promotion efforts, enhancing the level of development of pertinent industries, enhancing the effectiveness of market-oriented operations, enhancing the level of technological innovation and research capabilities, enhancing the level of technical coordination and application, and enhancing the cult of technology.

The sustainable construction of green structures is influenced by a variety of factors. There are still some limitations in the thesis research even though it aims to conduct in-depth and systematic research because of the restrictions of the objective conditions. The factors examined in the thesis are only a broad overview of those elements that have an impact on sustainable development, including different kinds and geographic locations of green buildings. Therefore, future research should further combine the variations in the development of green buildings of various types and regions to construct a more detailed list of influencing factors in categories and subregions and make effective recommendations. Second, expand data collection and refine the findings of the analysis. The significance, content, and interrelationships among these factors have changed as time has gone on. Second, increase data collection and refine analysis findings. The content, interrelationship, and importance of the influencing factors evolve along with the advancement of the times. As a result, they should be further studied in conjunction with the advancement of green buildings to collect increasingly accurate data and formulate more sensible recommendations.

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