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A Study on the Green Building Trend in China—From 2001 to 2022, Focusing on Research Topic Words

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Abstract: The Chinese government has committed to achieving carbon neutrality by 2060. Consequently, a shift towards green building development in the construction industry is inevitable. The purpose of this study is to summarize and predict the development direction of China's green buildings by understanding their changing trends over time. Accordingly, this study employed content analysis as the research method to analyze 69 research papers and their topic words published from 2001 to 2022, with further in-depth analysis from four sub-dimensions: technical, economic, policy, and systemic. Overall, since 2000, China's green building research has mainly focused on energy-saving technology and economic aspects, with particular attention being paid to the role of incentive policies. Research on the energy-saving renovation of existing buildings is insufficient, and research on building energy-saving management systems has been scarce. This may be related to China's emphasis on technology and its neglect of management functions such as operations and maintenance. Considering the important role of management in the construction industry, it is crucial for the academic community to strengthen research on a comprehensive and systematic green building management system and for the Chinese government to increase its support for green building management and practices.

Keywords: green building; sustainable development; energy-saving technology; economy; incentive policy; green building system

Citation: Ren, W.; Kim, K. A Study on the Green Building Trend in China—From 2001 to 2022, Focusing on Research Topic Words. *Sustainability* **2023**, *15*, 13505. https://doi.org/10.3390/su151813505

Academic Editor: Jurgita Antuchevičienė

Received: 9 August 2023
Revised: 6 September 2023
Accepted: 7 September 2023
Published: 9 September 2023

1. Introduction

At the 75th United Nations General Assembly, the Chinese government pledged to strive for carbon emissions peaks by 2030 and achieve carbon neutrality by 2060. However, China's construction industry is one of the most energy-consuming sectors. According to the Chinese Construction Energy Consumption Research Report (2020), construction-related carbon emissions accounted for 51.3% of the nation's total carbon emissions in 2018 [1]. Thus, urgent action is required within the construction industry to shift away from conventional high-energy consumption models and embrace green building development.

Research on green buildings in China has experienced significant growth since 2000. However, an imbalance exists in the emphasis on green building development with a primary focus on design and construction, as it neglects the critical aspects of operation, maintenance, and management. Additionally, the current system faces challenges in terms of unclear responsibilities and excessive reliance on government support [2].

It is challenging to encapsulate the entire research on green buildings in China within a single sentence. A considerable portion of the research conducted by numerous previous scholars has materialized. However, rapid and unpredictable changes in modern society raise doubts about the future trajectory of green building research and construction in China. To steer China's green buildings towards a more desirable path, it is crucial to comprehend the evolving trends and processes in China's green building research and development.

The objective of this study is to provide a summary of and forecast the green building development trajectory in China by examining the evolving trends within the field. This

study analyzes research keywords published between 2001 and 2022 and discusses green building changing trends in China over different periods.

2. Research Scope and Methods

A qualitative study has been conducted through content analysis of the literature. To understand changing trends in green buildings in China, this study collected research papers by searching academic journals (Chinese Science Citation Index level). China National Knowledge Infrastructure (CNKI), the prominent academic database in China, is used for paper search and selection, with search terms such as "green buildings," "eco-friendly buildings," and "energy-saving buildings." China's accession to the WTO in 2001 brought not only enormous opportunities for economic development but also many advanced technologies and management experiences. Thus, the covered period in this study starts in 2001 and continues until 2022, the most recent year for which annual data collection is available.

The research papers for analysis were chosen through a two-round selection method. In the initial round, the titles, abstracts, and keywords of all the preselected papers were examined to determine their alignment with the criteria. Subsequently, in the second round, each paper from the first selection phase underwent a comprehensive analysis to confirm its relevance to the research objective. In the end, a total of 69 research papers were ultimately chosen for inclusion.

3. Theoretical Background

Due to differences in the cultural, regional, and economic characteristics among countries, there is no consensus on the definition of green building among them.

There are three globally recognized green building elements: resource conservation and environmental protection; creating a comfortable and healthy living environment; and promoting harmony among people, buildings, and the natural environment. In addition, green buildings strive to maximize resource efficiency, provide comfortable and healthy living spaces, and reduce the impact of buildings on the surrounding environment as much as possible [3].

The U.S. Environmental Protection Agency defines green buildings as those that prioritize resource conservation and environmental responsibility throughout the building lifecycle. These include aspects such as location selection, design, construction, operation, maintenance, and renovation. The international community acknowledges these principles [3].

The concept of green buildings in Germany can be summarized as "energy saving, improving building functionality and quality, and enhancing residential comfort" [4]. As geographical location determines the importance of heating, reducing energy consumption is the most important aspect of green buildings in Germany while ensuring the quality of indoor thermal and air environments [5]. In 2013, the German Energy Conservation Act was issued, requiring new public buildings to achieve near-zero energy consumption starting from 2019 [6].

In Japan, while there is not a distinct definition for green buildings, a concept similar to it is the notion of environmental symbiosis housing, which is defined as "from the perspective of protecting the Earth's environment, closely integrating with the surrounding natural environment with occupants as the main part, creating a healthy and comfortable living environment, and emphasizing coordination and balance between them" [7].

In South Korea, a green building is defined as "one that minimizes environmental damage from construction to inhabitation and demolition." They are designed to create a comfortable residential environment, save resources, and protect the natural environment [8].

The China Green Building Evaluation Standard (2006) defines green buildings as those that maximize energy conservation and reduce emissions throughout the entire lifecycle, effectively protecting the ecological environment, and providing efficient and healthy

spaces for residents [9,10]. In addition, the "Action Plan for Green Building Creation" formulated in 2020 emphasizes the importance of strengthening green building operations and management and calls for legislation promotion to clarify responsibility among the various stakeholders [11].

Moreover, in recent years, the green economy concept in China has played an important role in promoting the development of green buildings. Current research often refers to the United Nations Environment Program definition (2011), which believes that the green economy developmental model is based on minimizing environmental risks and ecological damage, seeking low carbon and energy efficiency, and is a sustainable developmental model that balances social equity [12]. Green buildings are embodied carriers of the green economy in the construction industry. Green buildings can effectively reduce costs, energy, and resource consumption and create more job opportunities in industries such as design, construction, equipment, operation, and maintenance. In addition, green buildings can improve the quality of indoor work and life [13].

4. Green Building Changing Trends and Related Research Topics

The Chinese government is following a five-year cycle to formulate a national development plan that establishes economic and social development goals for the coming years. In accordance with this five-year cycle, we analyzed the selected 69 research papers during each five-year period, focusing primarily on technical, economic, and policy aspects. A framework for the objective analysis of the collected data was established by categorizing research literature subject words according to the research fields, and seven main areas were identified: energy-saving technology, economy, incentive policy, building energy-saving systems, building renovation, evaluation index systems, and building energy-saving management systems. Table 1 lists the corresponding keywords(s) in each study. In addition to the seven main areas, research areas that rarely appeared in various periods, including green building introduction, feasibility, and construction challenges, are all assigned to the 'Other' column in Table 1.

Table 1. Main subject keywords of the research papers by period (A is Evaluation index system, B is Energy-saving technology, C is Economy, D is Incentive policy, E is Building renovation, F is Building energy-saving management system, G is Building energy saving system, and H is the Other).

Period	NO.	Researcher (Year)	A	B	C	D	E	F	G	H
2001–2005	1	Sun Jingshui (2002) [14]								O
	2	Li Yunlan (2005) [15]	O							
2006–2010	1	Wang Xiuyan et al. (2006) [16]		O						
	2	Zhang Shilian et al. (2006 [17]				O				
	3	Zongsheng et al. (2006) [18]								O
	4	Liu Ying et al. (2007) [19]		O						
	5	Zhang Shilian et al. (2007) [20]							O	
	6	Yang Zhongdong (2007) [21]				O				
	7	Li Jing et al. (2007) [22]				O				
	8	Chen Yingcun (2008) [23]								O
	9	Zhang Xiangrong et al. (2008) [24]								O
	10	Liu Xiuli et al. (2008) [25]			O					
	11	Zhao Yuqing (2008) [26]		O						
	12	Zhu Ningning et al. (2008) [27]				O				
	13	Li Hui et al. (2008) [28]				O				
	14	Yan Jin (2008) [29]				O				
	15	Wang Jianlong et al. (2009) [30]		O						
	16	Wang Ning et al. (2009) [31]	O							
	17	Zhan Songlin et al. (2009) [32]			O					
	18	Chen Huamin et al. (2009) [33]	O							
	19	Cheng Min et al. (2009) [34]		O	O					
	20	Wang Ruozhu et al. (2009) [35]		O						

Table 1. *Cont.*

Period	NO.	Researcher (Year)	A	B	C	D	E	F	G	H
2006–2010	21	Qiu Baoxing (2009) [36]							O	
	22	Wang Runxia (2010) [37]								O
	23	Yang Jie et al. (2010) [38]						O		
	24	Liu Yuming et al. (2010) [39]				O	O			
	25	Zhang Li (2010) [40]			O					
	26	Guo Liqiao (2010) [41]							O	
	27	Qiu Baoxing (2011) [42]			O		O			
2011–2015	1	Lin Lin (2011) [43]		O	O					
	2	Yang Xiu et al. (2011) [44]							O	
	3	Li Wangming et al. (2011) [45]	O							
	4	Jiang Bo et al. (2011) [46]						O		
	5	Sun Ping et al. (2011) [2]				O				
	6	Niu Ben et al. (2011) [47]				O				
	7	Xu Binyan et al. (2011) [48]		O					O	
	8	Zhang Hui et al. (2011) [49]	O	O						
	9	Liu Yuming (2012) [50]				O				
	10	Zhang Qi (2012) [51]				O				
	11	Chen Manying (2012) [52]						O		
	12	Dou Zhijie et al. (2012) [53]			O					
	13	Ye Zuda (2012) [54]			O					
	14	Sun Hongxia (2012) [55]				O				
	15	Wang Fang et al. (2012) [56]	O		O					
	16	Anna (2012) [57]				O				
	17	Qiu Baoxing (2012) [58]								O
	18	Chen Hongbo et al. (2013) [59]		O						
	19	Yao Gang et al. (2013) [60]	O				O			
	20	Sun Yan et al. (2013) [61]	O							
	21	Li Ying et al. (2014) [62]			O					
	22	Shi Jiangang et al. (2014) [63]	O							
	23	Wang Li et al. (2015) [64]				O				
	24	Wei Xing et al. (2015) [65]				O	O			
2016–2020	1	Huang Zhiye (2016) [66]			O		O			
	2	Yang Wenling (2016) [67]	O							
	3	Wang Hong et al. (2017) [68]			O				O	
	4	Lu Bin et al. (2017) [69]		O					O	
	5	Sun Mingchun (2017) [70]			O					
	6	Bi Xiaojian et al. (2018) [71]		O					O	
	7	Du Hailong et al. (2018) [72]	O							
	8	Lin Yong(2019) [73]		O					O	
	9	Qin Wenjun et al. (2019) [74]		O		O				
	10	Zhao Jianxun (2019) [75]			O					
	11	Ji Xiaolei et al. (2020) [76]		O			O		O	
After 2020	1	Qiu Baoxing (2021) [77]				O				
	2	Zhang Jingyu et al. (2021) [78]		O					O	
	3	Li Nanshu et al. (2022) [9]						O		
	4	Wang Chong et al. (2022) [3]	O							
	5	Dai Lianghua et al. (2022) [79]	O							

4.1. 2001–2005

4.1.1. Changing Trends

From 2001 to 2005, China implemented its 10th Five-Year Plan, which highlighted green building importance in architectural development. During this period, the Chinese government formulated its policy objectives, specific measures, and guiding principles. These included building energy-saving technology research and application, green building and energy-saving technology promotion, and financial support expansion [80]. During

this period, China's research on green buildings mainly focused on green-building theoretical research and exploration. With the academic community's attention to the concept and theory of green buildings, discussions and research have been conducted on the definitions, principles, evaluation indicators, and other issues related to green buildings, laying the foundation for a green building standard system in China. Simultaneously, the Chinese government released the 2005 version of its "Energy Efficiency Design Criteria for Public Buildings [81]." Additionally, symbolic green building projects have emerged, as exemplified by structures such as the Shanghai Global Financial Center and the Guangzhou CITIC Plaza. These projects successfully integrated environmental protection and sustainable development principles into their architectural design and engineering, while meeting functional requirements, thereby contributing to environmental conservation and energy efficiency [82].

Based on research paper analysis from 2000 to 2005, China's green building research at the time mainly focused on introducing foreign green building concepts, evaluation indices, and certification systems. In particular, the U.S.'s LEED certification standard, Japan's environmentally symbiotic housing evaluation standard, and Korea's eco-friendly certification system development process and evaluation criteria have been widely introduced and studied in China. These foreign green-building certification standards and evaluation index systems have become important reference materials for establishing similar systems in China.

4.1.2. Research Trends

From 2000 to 2005, China's research on green buildings lagged behind that of other countries. However, the green building concept and theories began to receive attention and the emergence of practical projects has laid the foundation for green building development and progress in China.

4.2. 2006–2010

4.2.1. Changing Trends

From 2006 to 2010, China received widespread attention regarding green building development. During this period, the Chinese government and society gradually recognized the importance of building energy conservation and environmental protection and began to take a series of measures to promote green building development. The 11th Five-Year Plan played a crucial role by introducing supportive policies and goals for green buildings, including technology development, diffusion, and application; the development of new energy-saving materials; building energy-saving management; and the establishment of green building evaluation standards [83]. Research on green buildings in China during this period covered several key areas.

Several technologies have gradually been applied in energy-saving research and applications. These include solar power utilization, air-conditioning, and building-material energy savings. In addition, extensive research has been conducted on building insulation, lighting energy savings, solar water heaters, and geothermal heat pumps [84].

In the architectural design field, researchers began exploring green building design ideology with ecological sustainability as the core. Architectural integration with the natural environment and harmonious coexistence of humans and nature were emphasized. Concurrently, some researchers emphasized building energy use and environmental protection issues from design outset. For example, the School of Architecture at Tsinghua University presented a green design strategy suitable for architecture, including building orientation, window layout, and natural ventilation design [82].

Regarding standards and policy, the Chinese government issued a series of energy-saving standards and policies to strengthen energy conservation and emission reduction. The National Environmental Protection Agency published "Green Building Evaluation Criteria" to provide a scientific evaluation method for building energy conservation [28].

Researchers also explored building energy-saving management methods and tools. Building energy monitoring systems management software and energy saving and emission reduction assessment tools were included. For example, the building energy consumption simulation software and monitoring systems developed by the China Academy of Architecture have provided scientific support for energy-saving building management [85].

4.2.2. Research Trends

From 2006 to 2010, China's green-building research focused primarily on energy-saving technologies and incentive policies. Additionally, green building economic feasibility studies emerged during this period. Energy-saving technology research mainly focused on saving and utilizing water resources and improving wall insulation performance. Technologies for applying solar energy from renewable sources to green buildings were also proposed.

Green-building incentive policy research can be divided into economic and policy-based incentives. Economic incentives focus on subsidies and taxes. A subsidy policy provides money to producers and consumers (users) of green building products. Tax policies are divided into preferential and surcharges tax incentives for green building product producers and additional intensive taxation for non-green building product producers [17]. Policy-based incentives focused on long-term profits, such as resources, the environment, and society; avoiding short-term government action; increasing government reliability; strengthening energy-saving project monitoring; and promoting green buildings [29].

During this period, the life cycle cost (LCC) theory concept was introduced in green building economic research; however, its application was limited, and systematic research was lacking. As the economy grew rapidly during this period, research on green building economic feasibility emerged regarding real estate demand. To highlight the green building low market awareness issue, several proposals were made to strengthen their promotion, raise public energy conservation awareness, introduce economic incentives, rationally allocate energy-saving costs, and establish a building-energy-efficiency labeling system [32]. Research on the green renovation of existing buildings and energy-saving systems began in 2010.

Overall, during this period, significant progress was made in green building development in China, particularly regarding green building technology, promotion policies, and economic aspects. Existing building energy-saving renovation also began to receive attention.

4.3. 2011–2015

4.3.1. Changing Trends

From 2011 to 2015, China's green building research and application were further strengthened as an important strategy in creating a "resource-saving and environmentally friendly society" during the 12th Five-Year Plan [86]. Along with economic growth, important developments in green building research during this period were mainly as follows.

In the green building technology field, emphasis was placed on encouraging and supporting innovation and research development that promoted new energy-saving materials, techniques, and smart building technology. For example, various enterprises engaged in building insulation research and development introduced new energy-saving materials such as blue flint slabs, polyurethane insulation materials, and microstructural insulation materials [87].

To improve and disseminate green building standards, the government implemented and gradually completed a series of green building evaluation standards and policies. In 2013, the "Comprehensive Implementation Project Plan for Energy Saving and Emission Reduction" and "Green Building Promotion Plan" were announced, clearly presenting the goal and direction to promote green buildings extensively in the urbanization process [88]. New versions of "Green Building Evaluation Criteria" and "Building Energy Efficiency Evaluation Criteria" were published in 2014. It was the first comprehensive evaluation

criterion for green buildings in China and has played a role in regulating and expanding green building applications.

To promote green buildings, the government increased investments in exemplary green building projects during this period. Examples include the Shanghai World Expo exhibition hall and the Beijing Olympic Village, in which green-building technology and energy-saving techniques were applied to achieve significant energy-saving effects. These projects serve as exemplary green building practices that promote the application and dissemination of related technologies and concepts [89].

4.3.2. Research Trends

A published research study analysis from 2011 to 2015 showed a focus on green building evaluation systems, energy-saving technology, economic feasibility, and incentive policies. Foreign green building evaluation standards, improvements, and inspirational studies for China were mainly conducted. In energy-saving technology, unlike previous periods, the emphasis shifted to overall energy-saving measures and software design, and renewable energy source utilization such as solar and geothermal energy. In economic feasibility research, theories such as macroeconomics and LCC were used at the introductory level, as in the previous period, to analyze the green building economy.

Incentive policy studies were divided into economic and policy-based incentives, as in the previous period, but were more specifically refined. Different levels of incentive goals and targets were set, such as the central government's encouragement of local governments, the local government's encouragement of business owners, and business owners' encouragement of public building operation managers. The tax incentive policy for public building energy conservation was completed and the urban maintenance and construction tax was reformed and linked to energy consumption, making it available for use as an investment financing source for energy conservation in urban public buildings. A special building energy conservation fund was also established, and investment priority was given to conservation education, demonstration projects, new material and technology research and development, and basic theoretical research. In addition, investment and financing policies were reformed to support public building energy-saving renovation and maintain an energy-saving market mechanism [64].

In addition, a study targeting a specific area introduced the status of green building development in Beijing, major existing problems, and presented incentive policies for the city's green building development from 2011 to 2015 [50]. A study on green building economic incentive policy using game theory introduced policy effort strengthening through government and consumer behavior analysis and real estate tax exemption proposals, loan interest discounts, and direct subsidies to promote green construction [57]. Regarding existing building renovation, studies on the comprehensive evaluation of green buildings emerged [60]. Green building technologies and management systems for managing the entire life cycle using life cycle assessment (LCA) theory also emerged [52].

Overall, there was a qualitative leap in green building research during this period compared with previous studies. "Green Building Evaluation Criteria" and "Building Energy Efficiency Evaluation Criteria" were established. Qualitative progress was also made in the research on energy-saving technologies, incentive policies, existing building green renovation, and building energy systems.

4.4. 2016–2020

4.4.1. Changing Trends

Continuing development from 2016 to 2020, research on green buildings was listed as an important topic in the 13th Five-Year Plan. A "resource-saving and environmentally friendly society" accelerated goal was proposed, and a "green, low-carbon, and circular development" philosophy was proposed. During this period, the primary green building development research in China revolved around two aspects.

First is the innovative green building evaluation criteria aspect. In 2019, China released the third of its "Green Building Evaluation Criteria," the version introducing new evaluation items such as building intelligence and continuous operation. New technological requirements and evaluation criteria became more specific to green building design requirements [90]. In addition, the "Annual Development Report on Building Energy Efficiency in China (2017)" comprehensively examined building energy efficiency development status, challenges, and the future direction in China. Key issues identified included inadequate research investment, outdated technology, incomplete energy management systems, insufficient building energy-saving policies and standards, nascent green building market, and immature growth [91].

Second, continuous and in-depth energy-saving technology research was conducted. For example, various green building material aspects, such as exterior wall insulation, energy-saving window, and roof greening materials, were studied in depth. Simultaneously, China was actively exploring new energy-saving technologies, such as solar power, geothermal heat pumps, smart control systems, energy-saving building designs, and smart control systems to further improve building energy-saving performance. In addition, green building material research and applications such as biomaterials and building waste recycling, were actively promoted to reduce resource consumption and environmental pollution [92].

Moreover, the "China Smart City International Forum" held in Shenzhen, China in 2018 and the "Green Building and Smart City International Academic Conference" held in Xi'an, China in 2019 explored the interaction between green buildings and smart city development. Shortly thereafter, in 2020, the Chinese government announced its goal to achieve carbon neutrality by 2060 [77], highlighting its commitment to addressing climate change and promoting sustainable development.

4.4.2. Research Trends

From 2016 to 2020, China's green-building research primarily focused on energy-saving technology and economic aspects. In energy-saving technology, previous research findings emphasized overall conservation measures and building design. For example, regarding office complex buildings in cold regions, solutions appropriate for each stage were developed by following "overall layout," "building unit," and "building detail," design processes, thereby achieving the overall energy-saving objective [71]. Regarding economic aspects, unlike previous studies that focused on verifying economic feasibility, research in this period was mainly related to green finance, such as investment decisions and green building project financing. The researcher proposed the risk concept for green building project financing, which played an important role in enhancing participant enthusiasm, promoting successful fundraising, ensuring fund safety, and promoting healthy green building development [75]. In addition, based on overseas research, China's green building evaluation system was established and further expanded to include a discussion on green ecological city evaluation. Although interest shifted from theoretical exploration to practical application, China's green ecological city construction still required clear development goals and standard evaluation indicators that are important in city planning, construction, and management [72].

In summary, from 2016 to 2020, research on green buildings in China gradually evolved from partial and one-sided approaches to a more comprehensive and systematic perspective. The government's continuous policy support and promotional efforts laid a solid foundation for green building advancement and systematic research.

4.5. Post 2020

4.5.1. Changing Trends

The period 2021–2022 marks the beginning of the 14th Five-Year Plan in China, which highlights the importance of promoting efficient green building technology, green buildings, and renewable energy application in the construction field. The plan also introduces specific

measures, such as strengthening building energy consumption monitoring and evaluation, and enhancing building energy consumption management. Noteworthy developments in China's green-building research during this period encompass the following aspects:

First, green building standards have been raised. The "Green Building Energy Evaluation Criteria" 2021 version was released, which has created more stringent standard application and evaluation systems, improving the quality and effectiveness of green buildings. The requirements for energy consumption, indoor environments, building materials, water resource utilization, and other building aspects are more stringent, whereas ecological adaptability and circular reuse have introduced new evaluation criteria, such as building sustainability. In addition, the criteria specify the conditions and procedures for green building signage use [93].

Second, research on green building design emphasizes energy-saving concept integration into building design, which is crucial for green building construction. Researchers have used computer simulation technology to optimize building structures and layouts and reduce building energy consumption. For example, the School of Architecture at Tsinghua University designed an urban public building model that incorporated various clean energy sources such as solar and geothermal energy and wind power, achieving zero carbon emissions [94].

Third, green building intelligent control and management is achieved through technologies such as green building intelligence, the Internet, artificial intelligence, and sensors. East China Normal University developed a smart green building management system based on the Internet of Things and big data, enabling real-time monitoring and control of building energy consumption, environment, and safety [95].

Fourth, green buildings are becoming increasingly important in urban planning and researchers have proposed additional green building standards and guidelines. For example, the China Institute of Urban Planning and Design has issued the "Urban Green Building Technical Regulations," which set forth standards for urban green building design, construction, and operation and provide strong support for urban green construction [96]. As the sustainable architecture concept is increasingly popularized and promoted, the green-building market is gradually developing. In 2021, the Chinese government announced the construction of 100 national-level green building model areas by 2030 which will provide more opportunities and development potential for the green-building industry [78].

4.5.2. Research Trends

Based on an analysis of research published from 2020 to 2022, China's green building research has primarily concentrated on green building energy-saving technologies, building energy management systems, and eco-friendly research. Artificial intelligence application to building energy design has been presented in the energy-saving technology field. In the initial stages of housing planning, a method for designing energy-saving smart homes in cold regions in the north was proposed using parameter-based and artificial intelligence technologies based on the Grasshopper platform and Python language [78]. In the eco-friendly building field, the focus is not only on energy conservation but also on studying buildings from the user perception perspective, proposing a noise environment evaluation system for green buildings. As green buildings continue to develop, people's attitudes towards architecture are shifting toward constructing pleasant and eco-friendly buildings that contain various eco-friendly cultural elements [3]. Owing to the increasing noise pollution impact on residents' lives, suggestions and strategies for China's noise environment assessment standards have been proposed to maintain a suitable living environment for residents. Based on this situation, it is necessary to supplement the evaluation criteria for noise pollution and expand and divide green building evaluation rating indicators [79]. In the building energy conservation management system field, it was found that China's green buildings had design and construction emphasis problems, but neglected operation and maintenance. In this regard, it should be clearly stipulated that the owner or user should fulfill operational and maintenance obligations. Other stakeholders' obligations

and rights should also be clearly defined, incentive measures should be strengthened, and legal supervision should be strengthened [9].

Overall, since 2020, research on green buildings in China has focused not only on technology but also on the humanities. This lays the foundation for more systematic green building studies.

4.6. Brief Summary

From 2001 to 2022, there have been some changes in the focus and direction of green building research in China in response to growing energy consumption and environmental pollution problems and to promote sustainable development. Initially, the focus was on building materials and energy-saving technologies and green building evaluation systems and economics, such as passive solar buildings, building and thermal insulation, and green building evaluation system establishment and economic feasibility. Later, more emphasis was placed on the overall system design, investment, operations, geographical factors, and architectural microclimate. In addition, artificial intelligence technology has been applied to green building system design, and interest in factors other than energy saving, such as user comfort and noisy environments, has increased. Briefly, China's green building studies by period are as follows.

As shown in Table 2, from 2001 to 2005, China's green building research focused on establishing green building concepts and standards. From 2006 to 2010, the focus was on energy-saving technology development, economic feasibility, and incentive policies. From 2011 to 2015, research on energy-saving technologies, economic feasibility, and incentive policies continued to intensify based on previous studies, while actively exploring evaluation standards and improvement measures for green building evaluation systems. From 2016 to 2020, the focus was on comprehensive energy-saving technologies, building energy-saving designs, and green finance. Since 2020, the focus has been on the digitalization and intelligence of building energy-saving designs and the overall comfort of green building users.

Table 2. Main research contents by period.

Period	Research Focus
2001–2005	Green building concept, standards
2006–2010	Energy-saving technology, economic feasibility, incentive policies
2011–2015	Energy-saving technology, economic feasibility, incentive policies, evaluation systems (standards and improvement measures)
2016–2020	Comprehensive energy-saving technology, building energy-saving design, green finance
After 2020	Digitalization and intelligence of building energy-saving designs, overall comfort of green building users

5. In-Depth Analysis of Green Building Trends by Period

To understand China's green building research and development in depth, seven previously described fields were summarized and divided into four sub-dimensions: technical, economic, policy, and systemic. On this basis, according to research object content, each sub-dimension can be categorized into different elements. For example, the various detailed elements in the technical sub-dimension are divided into four sub-elements: energy utilization, building structure, building materials, and systemic energy-saving technology. Specific classifications of the four sub-dimensions and their elements are shown in Figure 1.

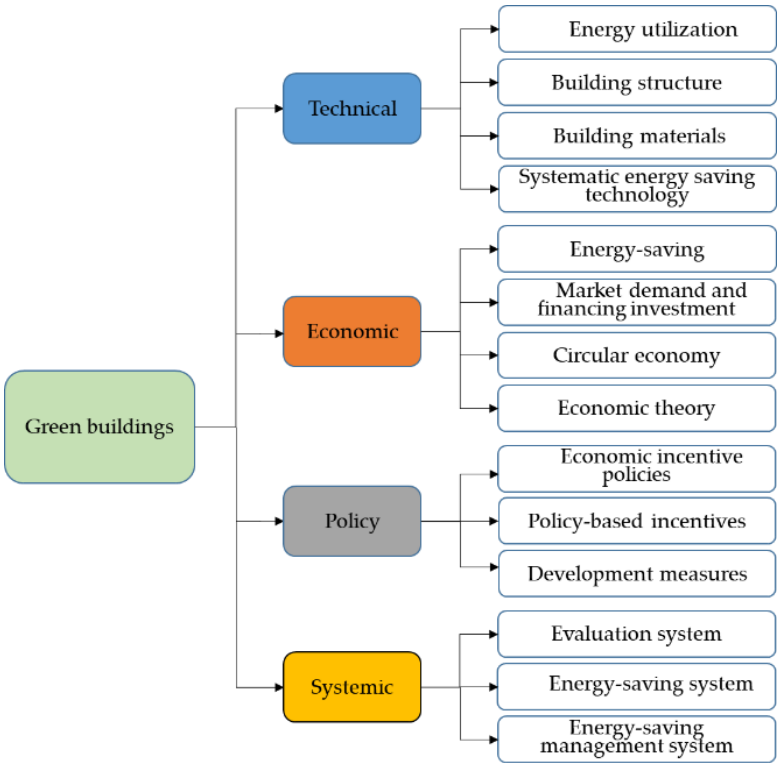

Figure 1. Classification of four sub-dimensions.

As shown in Figure 2, research on green buildings in China has gradually increased since 2005. From 2006 to 2010, research was conducted across four sub-dimensions. From 2011 to 2015, research on the technical and economic sub-dimensions decreased; however, research on the policy and systemic sub-dimensions continued to increase. This may be related to China's economic development slowdown during this period, and it is necessary to study how to support green building development from a policy perspective. Simultaneously, green building research and practice in China has developed to a certain extent, and systemic research and practice have become an inevitable trend. However, from 2016 to 2020, research on policy sub-dimensions decreased significantly. This may have been related to the relative stability of China's green-building policy during this period, which did not require frequent research and adjustment.

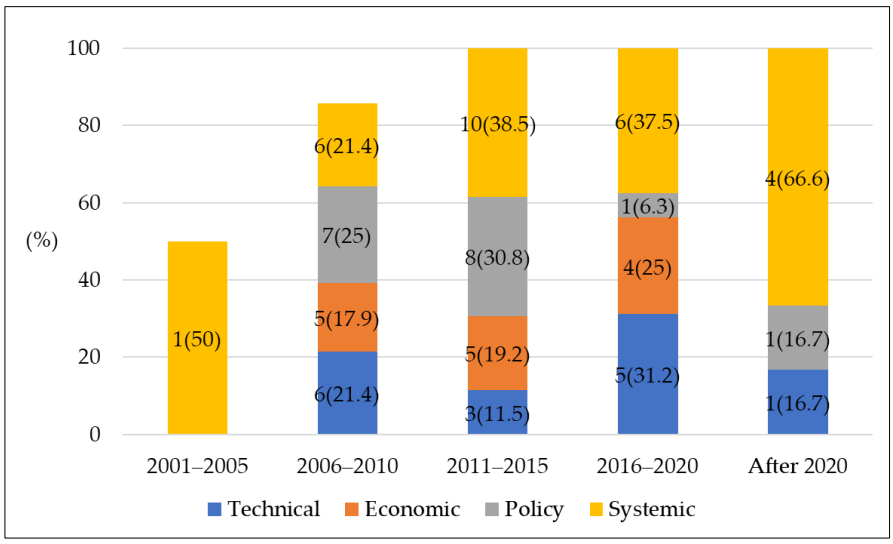

Figure 2. Research topic evolution trends in green building.

5.1. Technical Sub-Dimension

From 2001 to 2005, China's research on green buildings mainly focused on the concept and standardization aspects and on regulating green building development from a theoretical perspective. Since 2006, as the Chinese government has increased its interest in and promotion of green buildings, technological research on green buildings has continuously increased, as shown in Table 3 and Figure 3. Until 2015, research mainly focused on water and renewable resources, building walls, energy-saving materials, and other energy utilization, building structures, and materials. Beginning in 2006, research on systemic energy-saving technologies began to receive attention in China. Beginning in 2016, the focus shifted toward developing building model and energy-saving technology systems, energy-saving design and software, and systematic existing building renovations. This elucidates, to a certain extent, China's green building technical dimension research focus on energy-saving technology development before 2016. After 2016, the main direction shifted towards system energy-saving technology and building energy-saving design digitization and intelligence.

Table 3. Green building trends at the technological dimension.

Period	Energy Utilization	Building Structure	Building Materials	Systemic Energy-Saving Technology
2001–2005	0	0	0	0
2006–2010	4	1	0	2
2011–2015	2	1	1	2
2016–2020	1	0	0	4
After 2020	0	0	0	1

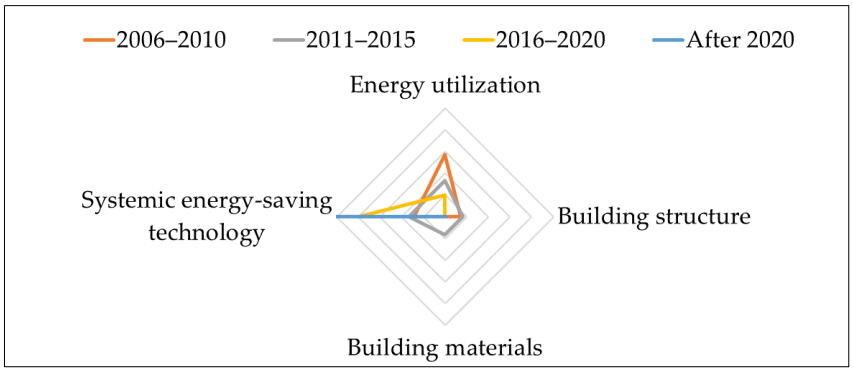

Figure 3. Green building trends at the technological dimension.

5.2. Economic Sub-Dimension

As shown in Table 4 and Figure 4, China's green-building economic research has progressed steadily since 2006. From 2006 to 2010, as the Chinese government paid attention to and promoted green buildings, the research content also increased. Specifically, the research focused on energy conservation, green building market demand and financing, investment, and the green circular economy. Research on green building market demand and financial aspects decreased from 2011 to 2015. Concurrently, even considering the lag in research paper publication time relative to economic condition performance, it can also be seen that it is related to China's lower GDP in 2011 and 2012 compared to that in previous years. Simultaneously, research on green buildings using economic theory also appeared during this period. From 2016 to 2020, with the Chinese government's strong green finance promotion, research on green building market demand and financing aspects, investment, and the green circular economy has become active again. Similarly, in existing building retrofitting terms, there has been a shift from research on renewable energy use and equipment retrofitting to research on green finance.

Table 4. Green building trends at the economic dimension.

Period	Energy Saving	Marker Demand, Financing Investment	Circular Economy	Economic Theory
2001–2005	0	0	0	0
2006–2010	2	2	1	0
2011–2015	1	0	1	3
2016–2020	0	2	1	0
After 2020	0	0	0	0

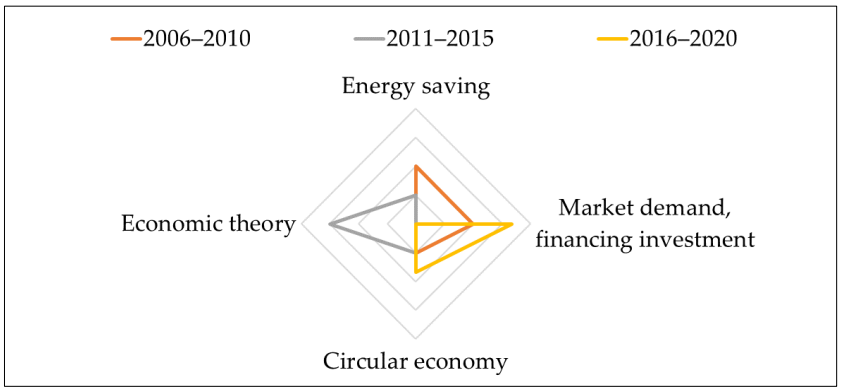

Figure 4. Green building trends at the economic dimension.

5.3. Policy Sub-Dimension

Since 2006, research on green buildings in China has gradually increased, and because of green building specificity, their dissemination has been inseparable from policy support. Policies can be divided into economic and policy-based incentives, and development initiatives (development measures). As shown in Table 5 and Figure 5, policy research was actively conducted from 2006 to 2015 and economic incentives and development policies weakened from 2016 to 2020. This is probably because, after the initial research and practice, the Chinese government had already issued a series of economic incentive policies and relatively complete guidelines. Moreover, at that time, China's economic level declined compared to previous years, and policy incentives were needed to promote green building development. Since 2020, with the increasing maturity of new technologies such as artificial intelligence and big data applications, supporting and promoting technology use to build green buildings has become a necessary focus of policy research.

Table 5. Green building trends at the policy dimension.

Period	Energy Incentive Policies	Policy-Based Incentives	Development Measures
2001–2005	0	0	0
2006–2010	3	3	1
2011–2015	4	2	2
2016–2020	0	1	0
After 2020	0	0	1

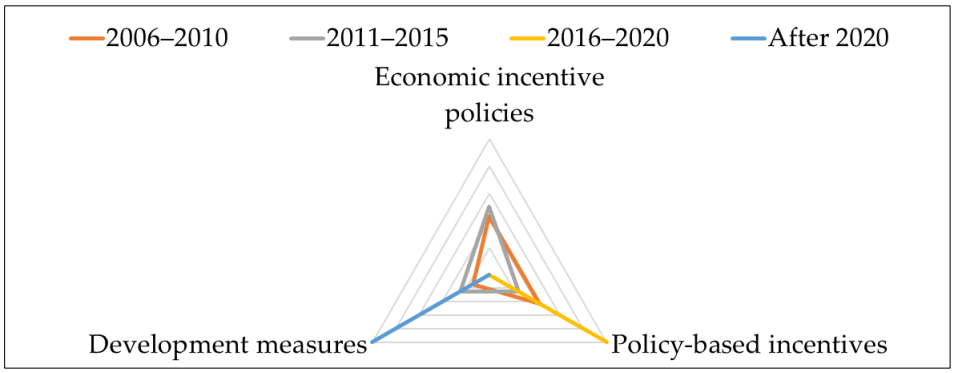

Figure 5. Green building trends at the policy dimension.

5.4. Systemic Sub-Dimension

In the 21st century, China's rapid economic development has brought green buildings into the spotlight. However, owing to a lack of understanding and evaluation standards for green buildings in Chinese society, the initial focus from 2001 to 2005 was on establishing an evaluation system. As shown in Table 6 and Figure 6, starting in 2006, as the green building concept spread, research on evaluation systems and building energy-efficiency systems proliferated. Relevant research continues to be promoted, especially in the field of building energy efficiency systems, from building energy efficiency model design to green city systems, and from residential energy-saving technology support systems to energy-saving design software. After the Chinese government promulgated the 2014 Edition Building Energy Evaluation Criteria, research on evaluation systems declined; however, studies on evaluation systems for retrofitting existing buildings have emerged. However, studies on building energy-management systems are limited. Some studies have introduced the building lifetime concept; however, no in-depth studies have been conducted. This may be related to the sparse relevant literature; however, it can be explained by a lack of research support for building energy management systems and a lack of interest by researchers because the Chinese government has emphasized the technical aspect and overlooked the management aspect.

Table 6. Green building trends at the systemic dimension.

Period	Evaluation System	Energy-Saving System	Management System
2001–2005	1	0	0
2006–2010	2	3	1
2011–2015	5	4	1
2016–2020	2	5	0
After 2020	2	1	1

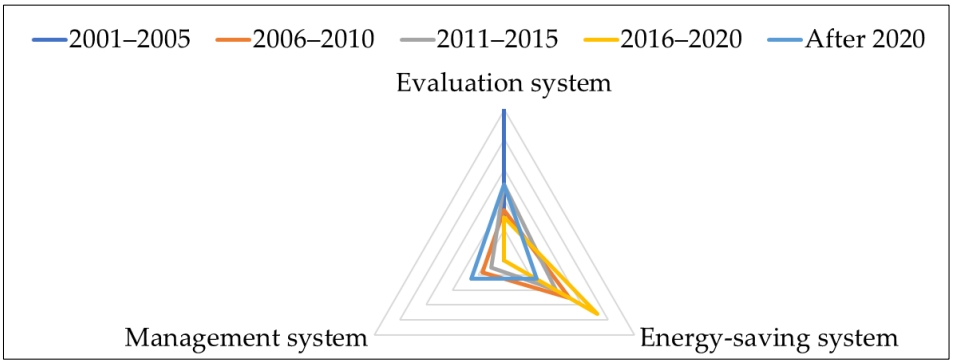

Figure 6. Green building trends at the systemic dimension.

6. Conclusions

Green building research and construction is significantly influenced by factors such as current requirements, culture, society, economy, and politics. The objective of this study is to provide a summary of and forecast the green building development trajectory in China by examining the evolving trends within the field.

This study examined green building research changing trends during different periods. Overall, Chinese green building research since 2000 has focused on energy-saving technology and economic dimensions, and attention has been paid to the role of incentive policies in promoting green buildings. However, research on retrofitting existing buildings is lacking, and research on building energy conservation management systems continues to be scarce. This may be because China values technology, yet neglects management. It may also be that green building research and construction are in their infancy.

Before 2006, China's green building research mainly focused on concept and standard formulation for green building theoretical regulation. Since 2006, research has been conducted in most areas with a growing focus on technological aspects. This trend became more pronounced after 2011, and gradually transformed into research on systematic energy-saving technology and digital and intelligent aspects of building energy-saving design after 2016. The policy dimension was active from 2006 to 2015; however, after 2016, research on the policy dimension decreased significantly. This may be related to China's relatively stable green-building policy, which does not require frequent research or adjustments. Since 2020, with increasing new technology maturity such as artificial intelligence and big data applications, supporting and promoting new technology use to build green buildings has become a necessary policy research topic. The economic dimension focused on energy saving, market demand, financing, investment, and the green building economy from 2006 to 2010. Research continued from 2011 to 2015; however, there was a decrease in research on market demand, financing, and investment. This may have been related to China's economic growth slowdown during this period. However, since 2016, with the Chinese government vigorously promoting green finance, research on market demand and financing, investment, green buildings, and circular economies, and other aspects has become active. Since 2006, studies evaluating building energy-saving systems have rapidly appeared. As the Chinese government promulgated building energy-saving evaluation criteria, research on the evaluation system has decreased; instead, it is actively exploring improvement of the evaluation system. Simultaneously, a study on an evaluation system for existing architectural renovations has also appeared. Since 2020, the main direction of research has changed to the digitalization and smartization of building energy-saving designs and research on the overall comfort of occupants.

Emphasizing technology and neglecting management are important problems that cannot be avoided during China's construction industry's development. In the green building field, management plays a crucial role in achieving energy-saving and emission-reduction goals as well as improving indoor environmental quality. Effective management not only prolongs building lifespan but also reduces operational and maintenance costs, contributing to green building economic viability. Therefore, the Chinese government should strengthen research and support for green building management, and when researchers use research methods such as LCA and LCC, they should gain a thorough understanding of the meaning and procedures of these research methods and then proceed with conducting in-depth and systematic research. It is also necessary to increase policy support for existing building renovations and research and formulate systematic renovation and evaluation standards.

With the Chinese government's growing emphasis on carbon emissions, research into the green renovation of existing buildings is expected to advance further. With the continuous development of China's economy, people's pursuit of green buildings will not only solely focus on energy saving but also gradually focus on the overall comfort of occupants. Therefore, research on improving the overall comfort of occupants will continue to advance forward. With the increasing awareness of the importance of construction industry management by the Chinese government and the growing maturity of new

technologies such as artificial intelligence and big data applications, the integration of these technologies into green buildings is bound to emerge as a pivotal avenue encompassing technology application, policy, economic study, systematic management, and investment.

This study focused on theme words related to green, energy-saving, and environmentally friendly buildings. The content is highly relevant; however, many studies from different periods may be missing. The research objects selected in this study were divided into 5-year intervals to correspond to the Chinese government's 5-year development plans. However, there is a paper publication time lag that requires attention. Therefore, it is necessary to improve these aspects in the future and conduct content reviews through a more in-depth literature analysis. Furthermore, the relationship between green buildings and China's needs, policies, and trends can be discussed in more detail. Contrastingly, the development of China's building industry in the past 20 years has benefited from rapid economic development; therefore, the results of this study are also applicable to developing countries with rapid economic development. However, even considering these research processes and methodological issues, changing green building trends over different periods, as demonstrated through the results of this study, can provide a reference for the future exploration of planning and specific solutions for green building research and construction in China and other developing countries.

Author Contributions: Conceptualization, W.R. and K.K.; methodology, W.R. and K.K.; validation, W.R. and K.K.; formal analysis, W.R. and K.K.; investigation, W.R. and K.K.; writing—original draft preparation, W.R.; writing—review and editing, W.R. and K.K.; supervision, K.K.; funding acquisition, K.K. All authors have read and agreed to the published version of the manuscript.

Funding: This paper was supported by Konkuk University in 2021.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

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