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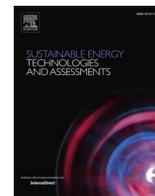
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Towards sustainable development: Analyzing policy frameworks and barriers in China's green construction transition[☆]

Zhengxuan Liu^{a,b}, Lin Zhou^{a,*}, Queena K Qian^b, Henk Visscher^b, Guoqiang Zhang^{a,*}

^a College of Civil Engineering, National Center for International Research Collaboration in Building Safety and Environment, Hunan University, Changsha 410082, China

^b Faculty of Architecture and the Built Environment, Delft University of Technology, Julianalaan 134, 2628 BL Delft, Netherlands

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ABSTRACT

Green construction transforms traditional construction practices by prioritizing energy efficiency, environmental protection, and long-term sustainability. With the construction sector accounting for 36 % of global energy consumption and 37 % of energy-related CO₂ emissions, the critical and systematic analyses of policy-based initiatives driving green construction and implementation barriers in China remain critically needed. This study addresses these gaps through a comprehensive mixed-method approach, incorporating extensive analysis of 189 publications, complemented by 9 in-depth interviews with experienced professionals (each with over 10 years of expertise). Key contributions include: (1) development of a multi-dimensional policy classification framework analyzing administrative, economic, and technological perspectives; (2) Systematic identification of five major implementation barriers through expert validation using Delphi methodology; (3) Successful international case studies are examined to offer comparative insights and targeted policy recommendations for China. This study also identifies key barriers and formulates practical solutions through a multi-stakeholder lens, integrating interview findings to enhance the relevance and applicability of the recommendations. The innovations encompass the integrated literature-expert triangulation framework for China's green construction policy assessment, combining policy document analysis with stakeholder validation to ensure robust findings. The study reveals critical policy gaps in interdepartmental coordination, financial mechanisms, and public engagement, while proposing actionable strategies including enhanced assessment systems, improved policy coherence, and expanded financial access. These findings provide evidence-based guidance for policymakers to accelerate China's construction industry transition toward carbon neutrality goals.

Introduction

In 2020, the construction sector accounted for 36 % of global energy consumption and 37 % of energy-related CO₂ emissions [1–3]. According to the United Nations Intergovernmental Panel on Climate Change (IPCC), the construction sector is responsible for over 32 % greenhouse gas emissions globally [4]. As one of the world's largest energy consumers, China contributes approximately 33 % of global CO₂ emissions [5,6]. With continued urbanization, CO₂ emissions from the construction sector are expected to rise future [7,8]. Therefore, reducing CO₂ emissions in this sector is essential to achieving China's carbon neutrality target [9–12].

Environmental issues are a growing concern, nearly all industries are adopting green measures and striving for sustainable development

[13–15]. With this broader trend, sustainable development in the construction sector has become not only a global imperative but also a national priority in China [16–18]. Green construction has emerged as a core strategy aligned with China's vision of sustainable development and the circular economy [16,19]. It plays a pivotal role in enhancing construction quality, promoting high-performance buildings, and achieving dual goals of environmental protection and economic transformation. The concept of green construction in China centers on improving production and construction processes in both urban and rural setting. It integrates green planning, design, and production, among others, aiming to deliver high-quality, environmentally friendly building products. Over the years, the Chinese government has issued a series of guiding documents to promote green construction, emphasizing its significance and necessity. These efforts align closely with the

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* Corresponding authors.

E-mail addresses: Lin_zhou2000@hnu.edu.cn (L. Zhou), gqzhang@hnu.edu.cn (G. Zhang).

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national goals such as building a “resource-saving and environmentally friendly society” and advancing the development of green buildings and construction conservation [20].

Despite policy progress, realizing China’s green construction goals requires not only technological innovation and professional skill development but also clear and effective policy guidance. Many current policies lack implementation details, and institutional, financial, and social barriers continue to hinder progress. Thus, it is essential to conduct a systematic analysis of green construction policies, explore existing barriers to implementation, and propose viable strategies to improve their effectiveness. Such analysis would support China’s broader ambitions in green development and sustainable urban transformation.

Green construction has attracted growing attention in academia, leading to range of important studies. For instance, He et al. [21] developed a comprehensive green development framework for China and applied functional data analysis (FDA) to model trends in green indicators between 2011 and 2018. Their results showed a consistent improvement in performance, in line with green development efforts. Miao and Li [22] analyzed the state of green construction in China and proposed practical solutions based on emerging trends. Similarly, Lina [23] clarified the conceptual link between green building and green construction, while Li et al. [24] emphasized the importance of green construction as a mechanism to realize sustainability goals in practice.

Researchers have also identified a range of obstacles to the promotion of green construction. Hwang et al. [25] conducted interviews and surveys with 31 industry experts and found that green construction projects, despite offering advantages such as enhanced quality and durability, face specific challenges such as high upfront material costs, the need for innovative techniques, complex stakeholder agreements, and longer approval times. Similarly, Hasan et al. [26] identified barriers in the Chinese context through a stakeholder survey, including underdeveloped technologies, poor management practices, and financial limitations. Furthermore, Shi et al. [27] examined key barriers through empirical analysis, identifying additional costs, extended project durations, and limited access to green suppliers and information as core issues.

Although the literature provides valuable insights, several critical research gaps persist: 1) Few studies systematically examined the evolution of green construction concepts and the sequential steps needed for its effective implementation in response to dynamic policy and market conditions; 2) Although policy incentives are central to promoting green construction, there is a lack of systematic evaluation of their effectiveness. Specifically, the literature does not adequately address which policy instruments are more effective under specific local conditions; 3) While some research has touched on implementation challenges, there is a lack of integrated analytical frameworks to assess barriers and propose actionable solutions grounded in China’s specific policy and institutional context.

To address these gaps, this study proposes a comprehensive and structured approach to analyze green construction policies and their implementation in China. The research aims to: 1) Develop a multi-dimensional framework for analyzing green construction policies from administrative, economic, technological, and public engagement perspectives. This framework enables a holistic understanding of policy dynamic and implementation performance; 2) Identify key barriers to green construction through expert interviews with nine senior professionals, each with over 10 years of experience in green construction research or practice. These expert insights, combined with a systematic summary of selected policy documents, provide a robust basis for analysis; 3) Formulate practical policy recommendations tailored to China’s institutional environment, with an emphasis on overcoming real-world barriers to promote effective implementation and long-term outcomes; 4) Contextualize China’s efforts in an international perspective, drawing on lessons from other countries to inform locally adapted strategies and policy innovation.

Green construction is crucial to achieving China’s dual-carbon goals and enabling the country’s transition to a low-carbon economy. By addressing research gaps and incorporating expert perspectives, this study presents a structured framework and evidence-based recommendations to support China’s sustainable construction transition. The remainder of this paper is organized as follows: Section 2 details the research methodology. Section 3 defines green construction and its role in current policies. Section 4 provides a comprehensive overview of policy initiatives for green construction at national and local levels. Section 5 analyzes policy documents and implementation in pilot projects, including international comparisons. Section 6 presents findings from expert interviews and proposed strategies for overcoming implementation barriers. Section 7 summarizes the conclusions and offers future research directions.

Methods

This study adopts a mixed-methods approach consisting of two key components: a comprehensive literature-based analysis and expert interviews. The combined methods enable a robust assessment of green construction policy implementation in China.

Literature and document analysis

The literature analysis forms the foundation of this study and includes three stages: (i) data selection, (ii) policy document collection, and (iii) content analysis, as illustrated in Fig. 1.

Journal articles were primarily retrieved from the Web of Science (WOS) database (from 1995 to 2024), following best practices in previous studies [28,29]. To ensure academic rigor, journals indexed in Scopus were given priority, and particular attention was paid to well-regarded publications such as *Building and Environment (B&E)*, *Energy and Building (E&B)*, and *Journal of Construction Engineering and Management (JCEM)* [30,31]. The search keywords included “green construction”, “green building”, “sustainable development”, and other related terms. Due to the broad scope of these keywords, the initial search results were filtered through title and abstract screening to remove irrelevant publications, particularly those not focused on green construction in China [32,33].

In addition to peer-reviewed articles, supplementary materials were incorporated to enrich the dataset. These materials included Chinese-language studies accessed via the CNKI (China National Knowledge Infrastructure) database and policy documents retrieved from official government sources such as Ministry of Housing and Urban-Rural Development (MOHURD) and the National Development and Reform Commission (NDRC). All policy documents were selected based on relevance, issuance authority, and policy scope. The complete list of policy sources and URLs is provided in Table A-1 (Appendix A).

After systematic screening, a total of 189 relevant documents were selected for further analysis. These include national regulations, green building standards, implementation guides, and strategic frameworks. They serve as the core dataset for identifying policy instruments, implementation status, and key barriers.

Expert interviews

To complement the document analysis and validate findings, expert interviews were conducted. A total of nine experts were purposefully selected based on their professional experience in green construction research, policymaking, or project development. The experts were categorized into three groups: three academic researchers in sustainable construction; three officials from the Green Construction Association and related government departments; three corporate executives involved in green construction projects. Each expert had over ten years of experience in their respective fields. Semi-structured interviews were conducted to gather in-depth perspectives on practical barriers to policy

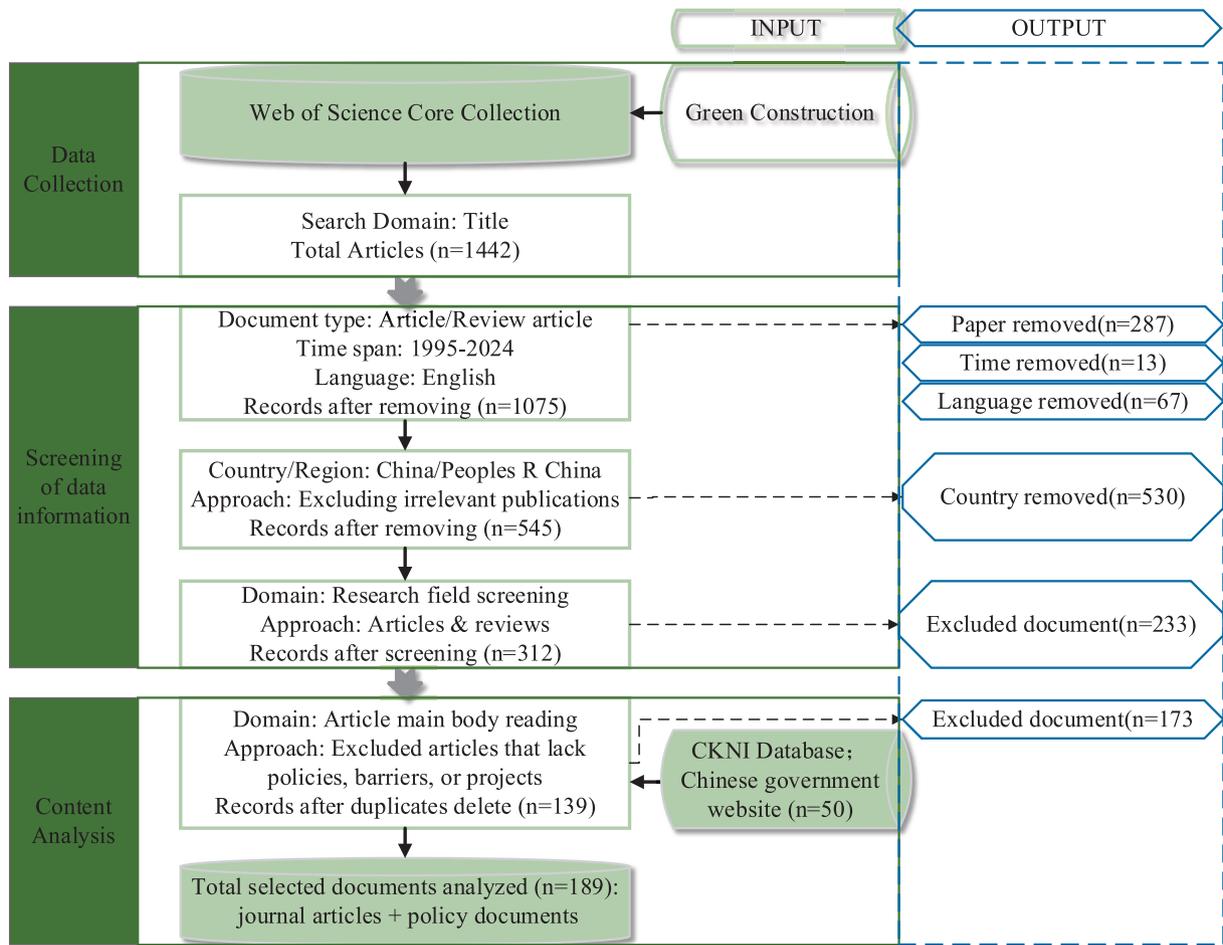


Fig. 1. Data collection and screening process for green construction policy and literature analysis.

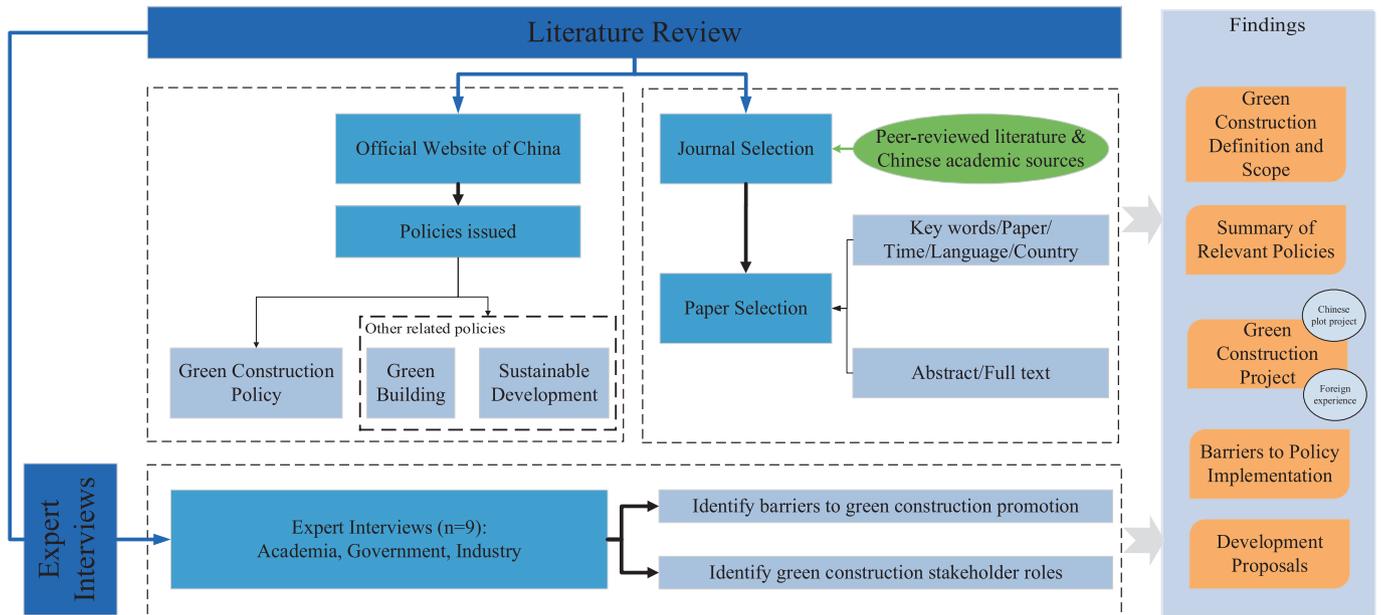


Fig. 2. Research contents of this study.

implementation and to refine the multi-dimensional analysis framework. The details of the interview protocol and analysis approach are discussed in Section 6.1.

The combination of literature and expert-based analysis led to the development of a comprehensive understanding of the barriers hindering green construction in China. The overall research content and methodological structure are illustrated in Fig. 2.

Conceptual framework and policy Functions of green construction

Concept definition of green construction

Green construction was formally introduced into China’s policy discourse in 2010 [34], evolving from the concepts of green buildings and green design. Over the past decade, its definition has matured through continuous practice and strategic development. Green construction integrates advanced management methods with traditional construction processes, emphasizing “intensification, industrialization, informatization, and greenization” in all phases of construction. The primary goal is to construct high-quality green buildings that are resource-efficient and environmentally responsible, while also aligning with people’s expectations for improved quality of life. In essence, it represents a transformative upgrade from traditional construction approaches.

In China’s policy system, green construction is guided by both government regulation and industry association initiatives. It is embedded in a structured process involving green planning, green design, green production, and green delivery [35]. Each stage engages specific stakeholders, ensuring a continuous feedback loop for quality and sustainability. In the green planning stage, planners develop an overall plan for the green construction process. After planning, the process advances

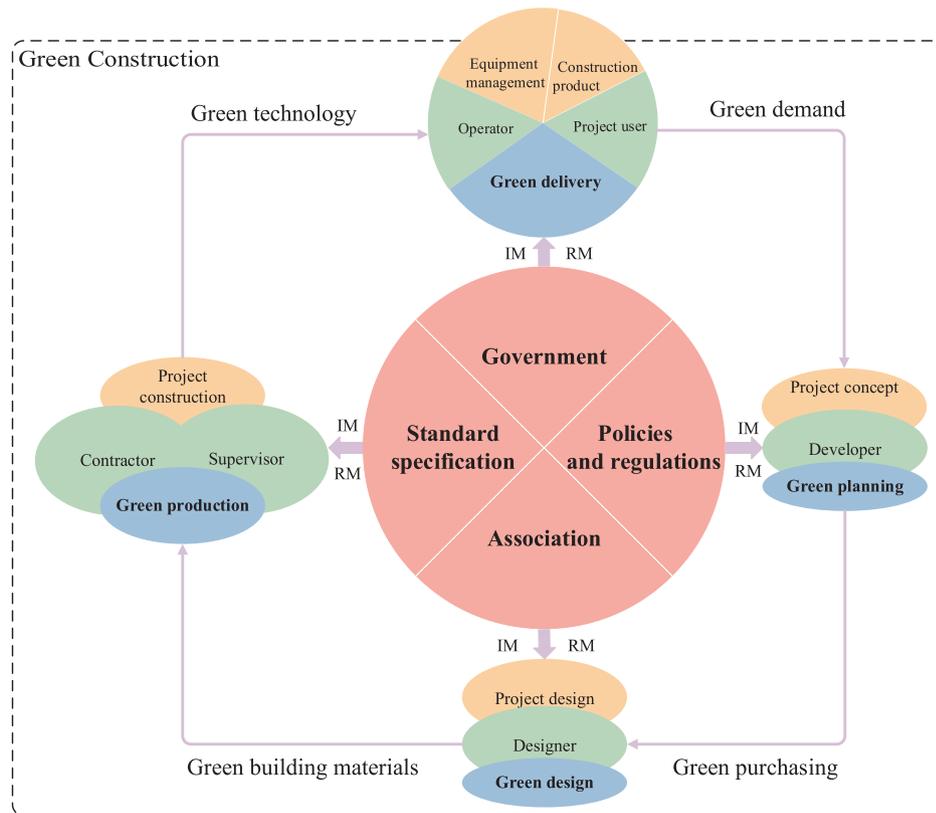
to the green design phase through green purchasing, where designers implement green development concepts. Upon design completion, the use of green materials is incorporated into the production stage. During the green production stage, contractors and supervisors conduct construction activities in alignment with green requirements. Any issues in the delivery process are addressed in subsequent green planning stages, enabling a green cycle across these four stages. A schematic model is presented in Fig. 3 to illustrate this integrated operation mechanism [36]. With the practical exploration of green construction activities, the definition of green construction has evolved and changed at each stage, as shown in Fig. B-1 (Appendix B).

Analyzing national-level policy documents reveals that green construction is a dynamic and adaptive concept, evolving with the shifting priorities of China’s construction and sustainability agendas. As Kibert [37] noted, it emphasizes the construction process itself-energy efficiency, pollution control, and environmental management-over merely the final building outcome. However, narrow definitions that focus solely on environmental aspects risk neglecting the social, institutional, and economic dimensions of sustainability. Thus, the policy definition of green construction has gradually expanded to include multidimensional goals and more ambitious performance requirements.

This evolving conceptual foundation plays a pivotal role in shaping the policy instruments and stakeholder actions discussed in Section 4, and serves as the basis for understanding the systemic barriers analyzed in Section 6.

Functionality and strategic roles of green construction

Green construction augments the traditional objectives of construction activities, encompassing “quality, safety, schedule, and cost” by incorporating “environmental protection and resource conservation”. This emphasis promotes national and local sustainable development,



Note: IM: Incentive mechanism; RM: Restriction mechanism.

Fig. 3. Schematic diagram of structure model and operation mechanism for green construction [36]. Note: IM: Incentive mechanism; RM: Restriction mechanism.

environmental protection, and efficient resource utilization. The construction sector in China contributes significantly to total carbon emissions, with the production stage of green materials and the building's operational stage being the primary contributors. Green construction activities encompass green planning, green design, green production, green delivery, the utilization of green materials, and green devices. These endeavors collectively strive to achieve greening, industrialization, informatization, intensification, and standardization [38].

From a policy functionality perspective, green construction achieves several strategic outcomes: i) Improving environmental benefits: Green construction significantly enhances energy efficiency, leading to extensive environmental benefits. These benefits encompass building energy efficiency, optimized land use, improved indoor air quality, and efficient construction/demolition waste management [39]. Notably, green construction effectively reduces various types of pollution and maximizes the use of renewable resources, thereby promoting sustainable development; ii) Reducing carbon emissions: China promoted the green building strategy to reduce the country's carbon emissions. The life-cycle carbon emissions of green buildings in China were reduced by 10 % for residential and 32 % for commercial buildings, respectively [40]. In recent years, the concept of green construction has prevailed in China, and it has also prompted many buildings to achieve green building, thereby reducing carbon emissions to a greater extent; iii) Optimal use of resources and energy: Energy-efficient technologies in the green construction sector can provide long-term savings to building owners. Data shows that LEED-certified green buildings are expected to save \$1.2 billion in energy costs and \$149.5 million in water savings due to energy-efficient technologies [41]. Clean energy utilization in green construction reduces the reliance on energy-intensive and time-consuming materials, optimizing resource utilization; iv) Promoting employment: Green construction activities involve sub-activities such as energy-saving retrofitting, technology development, and green indicator monitoring, which create a large number of new jobs available to more citizens [42], thus effectively contributing to employment.

Beyond these quantifiable benefits, green construction is aligned with broader urban renewal and industrial modernization strategies, as emphasized in national development plans such as the 14th Five-Year Plan and the "Urban Renewal Action" initiative. Carbon neutrality is both a driving principle and a fundamental requirement for future green construction practices. These multiple roles and expected outcomes shape the design of China's green construction policies, which are systematically examined in Section 4 through a national and local lens.

However, achieving these strategic outcomes faces significant constraints that must be acknowledged. Cost limitations remain a primary barrier, with green construction projects typically requiring 5–15 % higher initial investment compared to conventional approaches, despite long-term savings potential. Scalability challenges emerge when attempting to replicate pilot project successes across diverse regional contexts, as demonstrated by the varying implementation rates across different provinces. Technical constraints include limited availability of qualified professionals and suppliers, particularly in less developed regions, which restricts the widespread adoption of advanced green technologies. Performance uncertainty regarding long-term durability and maintenance requirements of some green materials creates hesitation among developers and investors. These limitations suggest that future research should focus on developing cost-effective materials, standardized implementation protocols, and comprehensive professional training programs to address scalability and technical capacity constraints.

Policy initiatives for green construction development: national and local perspectives

Policy-based initiatives from national governments

The development of green construction in China reflects a synergistic

interplay between standards, technologies, policies, and market mechanisms. Among these, government policies play a decisive role in guiding and accelerating the green transformation of construction sector [43]. Unlike many countries that rely primarily on market incentives, China's green construction development is largely state-driven. The government, along with industry associations such as the China Construction Association, provides strategic guidance to encourage enterprises to adopt green construction practices. This collaborative approach has contributed to the establishment of a resilient and sustainable construction market in China [27].

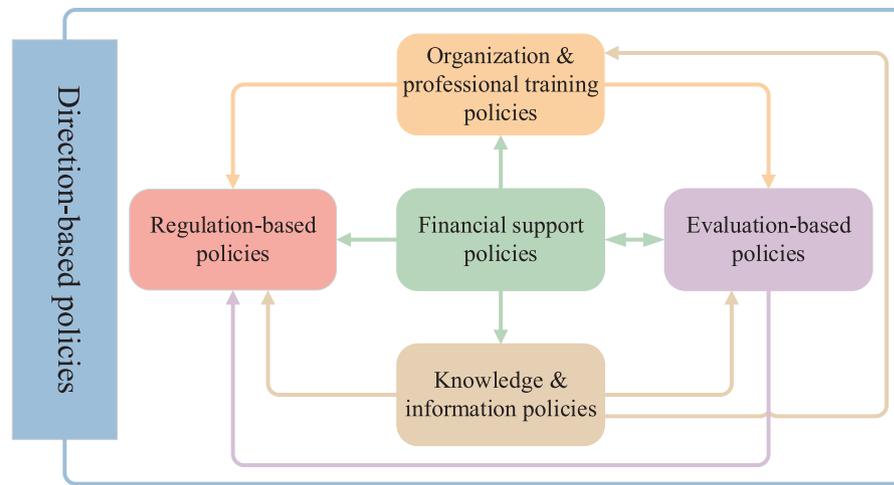
To accelerate the sector's green and low-carbon transition, the Chinese government has implemented a series of targeted policies at the national level. These include dedicated green construction policies and broader green building policies that contain green construction-related contents. These documents, jointly or independently issued by the Ministry of Finance, the Ministry of Housing and Urban-Rural Development, the Ministry of Science and Technology, and the National Development and Reform Commission, reflect a coordinated multi-agency effort. A summary of major national-level green construction policy initiatives is provided in Fig. B-2 (Appendix B) [44–61].

With the gradual implementation of China's "14th Five-Year Plan", a large number of researchers have found renewed motivation and competitiveness to promote green and low-carbon transformation through policy support. Green construction is a typical representative of green transformation in the construction field. From the perspective of policy content, green construction has experienced a progressive transformation from germination, discovery, and attention to shaping. From the perspective of policy time sequence, it can be divided into four stages: 1979–1995, 1996–2012, 2013–2020, and 2021 to present [62]. Key policy milestones include the "Ninth Five-Year Plan", which first recognized sustainable development as a national strategy, and the 2020 commitment to achieve carbon neutrality by 2060 announced at the United Nations General Assembly.

These policy documents emphasize the importance of reducing resource consumption and carbon emissions throughout the construction lifecycle, while encouraging the adoption of green standards in planning, design, construction, and operation. They also underscore the strategic positioning of green construction in achieving China's long-term sustainability and development goals.

To better understand the structure and logic of national policies, this study categorizes them into six interrelated types: direction-based policies, financial support policies, regulation-based policies, evaluation-based policies, organizational and professional training policies, and knowledge and information policies [63]. These policy categories are interdependent and interlinked, collectively promoting the positive development of green construction, as illustrated in Fig. 4 [64].

Direction-based policies serve as the foundational guidance for the other five policy types, offering future directions to promote green construction. These policies aid stakeholders in comprehending the advantages and future trends of green construction, steering construction activities towards the ultimate goal of greening, industrializing construction methods, information construction means, intensifying construction management, and innovating construction technologies [65]. Financial support policies span a range of types, including subsidies, tax exemptions or reductions, carbon tax implementation, and related funds [66]. These policies profoundly impact the effective implementation of other policies and the efficiency of construction activities, encompassing professional training, raising public awareness, and conducting energy audits [67]. Regulation-based policies involve the use of laws, regulations, statutes, and standards to achieve government objectives [68]. However, these policies often face challenges in efficient implementation due to high initial costs [69]. Financial support policies have proven effective in overcoming these barriers [70]. Providing subsidies or incentives can mitigate resident resistance to regulatory measures. Knowledge and information policies aim to enhance stakeholder awareness [71,72]. Public participation activities,



Note: the arrows indicate the important support relationship between policies.

Fig. 4. The relationships of different policy-based initiatives [64]. Note: the arrows indicate the important support relationship between policies.

serving as essential information tools, are crucial for promoting green construction development in China [73]. Combining regulations with information tools, knowledge, and information policies can improve their effectiveness, thereby contributing to the successful implementation of other policies. Evaluation-based policies encompass standards for evaluating various technologies and building grades used in green construction activities. This includes building energy surveys, diagnostics, assessments, and labeling. These policies can be categorized into ex-ante assessments, evaluating the necessity and feasibility of green buildings, and post-evaluations, determining the effectiveness of green construction [74]. Organizational and professional training policies involve establishing relevant professional associations and providing competent experts for green construction [63]. Professional training plays a vital role in increasing the involvement of various stakeholders while strengthening practitioners' skills and knowledge in green construction [75]. Therefore, organizational and professional policies can effectively support regulatory and evaluative policies.

These six categories of policies are interconnected and mutually reinforcing. Financial incentives can help overcome the resistance to

regulatory enforcement, while information dissemination and professional training can enhance compliance and innovation. A well-coordinated mix of these policy instruments contributes to the overall governance effectiveness of green construction implementation.

While national-level policies provide the foundational direction for green construction, their successful implementation often depends on localized interpretation and adaptation. The next section examines how provincial and municipal governments have contextualized these national policies through tailored regional initiatives.

Policy-based initiatives from local governments

China is currently undergoing an unprecedented and massive urbanization process [76], local governments have played an increasingly important role in adapting and operationalizing national green construction policies. Due to regional disparities in economic structure, industrial development, and environmental conditions, it is essential for provinces and municipalities to formulate their own policy measures in alignment with local needs and priorities. The policy intensity of each

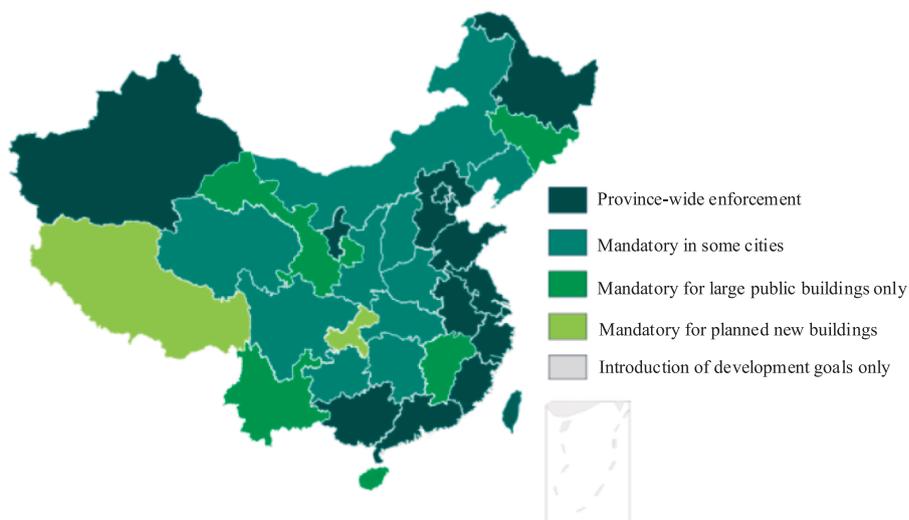


Fig. 5. Distribution of green building incentive policy intensity in China [77].

region is shown in Fig. 5, where darker colors indicate stronger and more widespread policy implementation [77]. From Fig. 5, it can be seen that coastal cities have the highest intensity, followed by cities with higher GDP in the central region, like Hunan Province and Hubei Province. In recent years, there has also been a growing interest at the local government level in promoting green construction. Jiangsu Province, Heilongjiang Province, and other provinces released the “14th Five-Year Plan” for developing the construction industry, and are proposed to vigorously promote green construction methods to achieve green and sustainable development of the construction industry.

In recent years, some regions in China have formulated green construction-related policies tailored to their specific characteristics, as depicted in Fig. 6 [78–91]. Coastal cities such as Guangdong Province and Jiangsu Province have a multitude of policy documents related to green construction, followed by the central region’s Hunan Province, which exhibits a wide array of policies in this domain. The main reason

is the geographical location advantage and faster economic development. Guangdong Province and Jiangsu Province, as China’s economic powerhouse provinces, these regions have embraced numerous advanced green technologies and construction specifications, covering a substantial area of green buildings. Their policies reflect their commitment to implementing green construction methods and achieving sustainable development in the construction industry. Conversely, Hunan Province stands out for its robust capacity to implement corresponding national policies, showcasing significant achievements in advancing the construction industry’s high-quality development. Over the recent years, the province has embraced the overarching notion of “green housing and construction”, steering urban construction and revitalization with eco-friendly, low-carbon principles. Moreover, being one of China’s major hubs for assembly building industries, Hunan Province boasts comprehensive industrialized facilities, along with a conducive environment for the growth of the green construction sector.

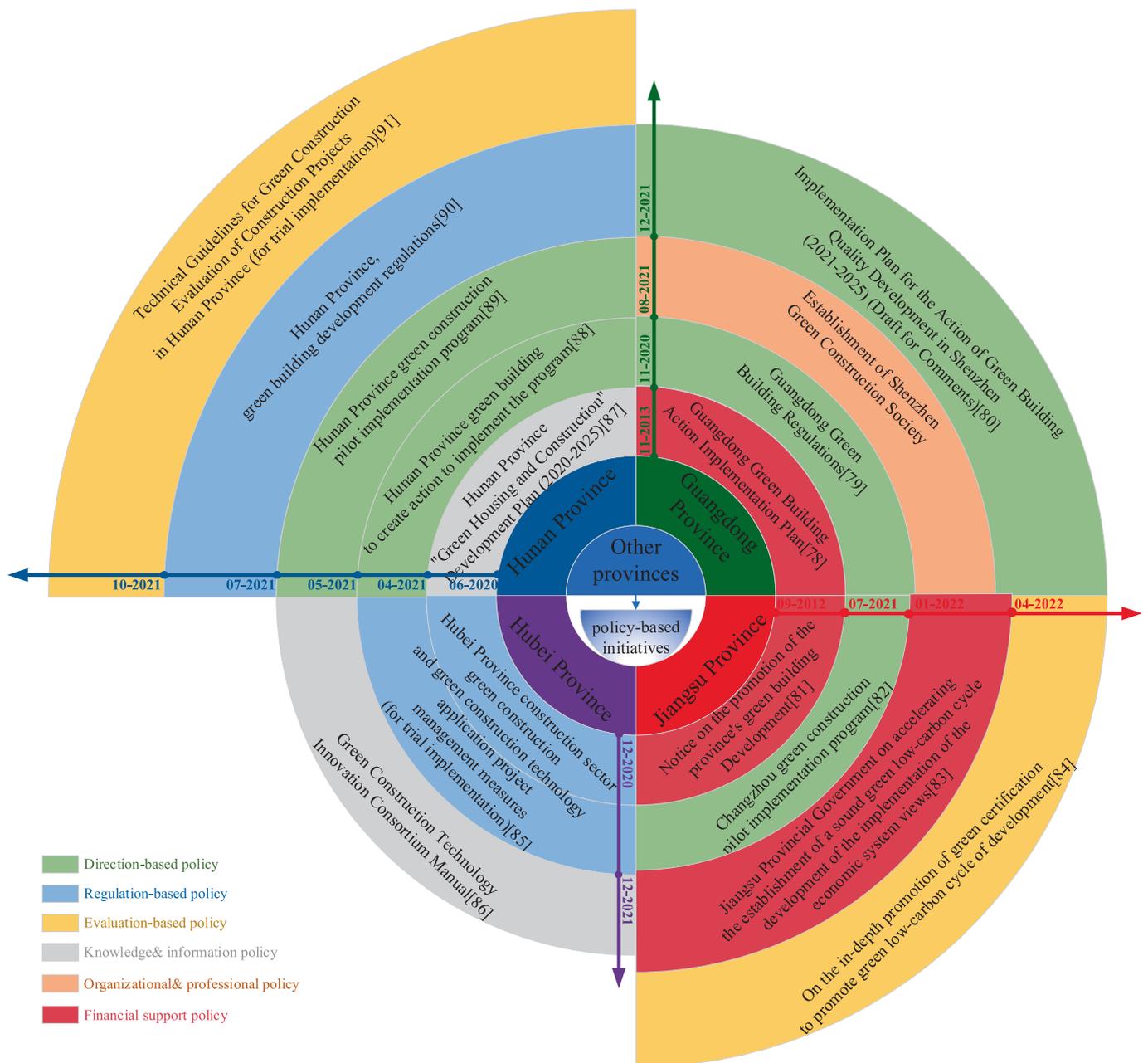


Fig. 6. Local policy-based initiatives related to the field of green construction [78–91].

Consequently, the province has proactively introduced a considerable number of policies centered around green construction in recent years, effectively propelling the sector's transformation towards high-quality and sustainable development.

These localized policies not only complement national-level guidance but also serve as key platforms for experimentation and innovation, creating valuable insights for refining national policy frameworks. Their implementation outcomes are further examined in the next section through pilot project evaluation and cross-national benchmarking.

Implementation practices and international benchmarking in green construction

Implementation of China's green construction pilot projects

The increasing emphasis on green development in China, coupled with the proliferation of policies, has significantly motivated construction practitioners to engage in green construction activities. In January 2021, the Ministry of Urban, Rural and Housing Construction of China announced the first batch of green construction pilot project cities, including Hunan Province, Changzhou City (Jiangsu Province), and Shenzhen City (Guangdong Province) [53]. These pilot regions target different project types (e.g., residential, industrial, and public infrastructure) and cover the full project lifecycle from planning to delivery. The primary goal is to foster a culture of green production and sustainable lifestyles while establishing replicable standards, management protocols, implementation guidelines, and evaluation criteria for green construction by 2023. These measures aim to expand green construction beyond pilot regions, driving the building industry's transformation and promoting sustainable urban and rural development [53]. Each pilot region has implemented key initiatives alongside policy support to achieve these goals, as summarized in Table A-2 (Appendix A).

The green construction pilot projects in various provinces are aligned with the national-level green construction pilot implementation plan and related policies, progressively advancing with the backing of fiscal policies and regulatory assessment policies. These initiatives comprehensively embrace and integrate prefabrication, green building, and digital construction technology, aspiring to establish national green construction demonstration benchmark projects [76,92]. These endeavors are expected to transform the pilot areas into leading domestic and internationally influential green construction technology innovation centers.

As the sole pilot province, Hunan Province possesses significant strengths in advancing green construction initiatives [93]. The "Green Construction Pilot Implementation Plan of Hunan Province" serves as a critical guiding policy, steering pilot projects toward green, digital, industrialized, and intensive development under the principles of government leadership and market-driven promotion. The "Green Construction Evaluation Standards for Construction Projects in Hunan Province" is an evaluative policy—a set of standards tailored to Hunan Province's unique characteristics—to assess the entire activity cycle of green construction. These standards not only ensure operational efficiency but also promote sustainable and high-quality development in the construction sector. Moreover, to strengthen scientific and democratic decision-making in urban and rural construction management, Hunan Province established the Green Construction Expert Committee. This committee addresses major strategic and technical challenges, offering solutions to complex issues in the green construction field [94]. Through the comprehensive implementation of these initiatives, Hunan Province has emerged as a benchmark for green construction in China, paving the way for the nationwide adoption of green construction practices.

By the end of 2023, Hunan Province had achieved significant quantitative outcomes: constructed 360 million m² of green buildings, and identified 9 projects as the first batch of green construction pilot projects, covering different types such as terminal buildings, scientific research office buildings, commercial housing, school buildings, tourism buildings, industrial buildings, etc., with a total construction area of 1.8085 million m². Notably, Hunan Province implemented 148 million m² of prefabricated buildings in 2023, accounting for 37.2 % of the total construction area, ranking among the top in China [95]. From January to May 2024, the proportion of prefabricated building areas in newly started urban housing reached 53.5 %, a year-on-year increase of 18.8 %.

Similarly, Changzhou City has achieved notable progress during its three-year green construction pilot program. The city developed a comprehensive policy guidance and support system, including a management mechanism and evaluation framework covering the entire construction process. It issued the nation's first local green construction standard, the Changzhou Green Construction Evaluation Standard, which has become a reference model for other regions. Changzhou also established two batches of 20 pilot projects, including innovative demonstration projects like the first rail transit green construction project and the Smart Integrated Energy Station No. 1 Energy Substation. These initiatives have produced replicable best practices that can be promoted across the country [96]. Building on Changzhou's success, Jiangsu Province has introduced the Implementation Plan for Expanding the Green Construction Pilot Program, scaling up pilot initiatives to accelerate the transition to green construction [97].

Despite these achievements, pilot project implementation reveals several critical limitations that constrain broader adoption. Geographic scalability constraints become evident when considering the varying economic development levels, climate conditions, and institutional capacities across different regions in China. Financial sustainability limitations emerge as pilot projects often rely on substantial government subsidies and policy support that may not be sustainable or replicable at larger scales. Technical standardization challenges arise when attempting to transfer technologies and practices developed in specific contexts to regions with different resource availability and skill levels. Coordination complexity increases exponentially when scaling from individual pilot projects to comprehensive regional implementation, as demonstrated by the coordination challenges identified in our stakeholder analysis. Future research should prioritize developing adaptive implementation frameworks that can accommodate regional variations while maintaining performance standards, and creating sustainable financing mechanisms that reduce dependence on government subsidies.

Foreign green construction development experience and summary

International experience offers valuable lessons for China's green construction transition, particularly in areas such as governance design, technological innovation, quality assurance, and behavioral incentives [98]. This study draws on practices from United Kingdom, the United States, and Singapore as benchmarks, as shown in Table 1.

Environmental protection in the construction sector is achieved through stringent control of on-site emissions, including dust, noise, exhaust gases, and wastewater, as well as the effective management of construction waste. These measures are essential to minimize the environmental impact of construction activities. The UK, as the birthplace of the Industrial Revolution, was among the earliest nations to confront industrial pollution. In the domain of air pollution control, strict regulatory measures are enforced on emission sources such as construction dust [99]. For water pollution, the UK has implemented a robust

Table 1
Typical measures in green construction across selected countries.

	The United Kingdom	The United States	Singapore
Environmental Protection	Clean Air Strategy 2019 [99], Discharges to surface water and groundwater: Environmental permit [100], Landfill Tax Rates 2023–2024 [101]. Net Zero Strategy: Rebuilding Greener [102].	Paris Agreement [103], Clean Competition Act [104], National Recycling Strategy [105].	Sustainable Building: A Guide to Using Recycled Materials [106], Singapore Green Development Blueprint 2030 [107], Singapore's Long-term Low Emission Development Strategy [108], Carbon Pricing Act [109].
Technological innovation	Envelope design, building ventilation, and wind energy utilization, solar photovoltaic power generation [110].	Standard for Construction and Safety of Manufactured Houses [111], National BIM Plan [112].	Transformation Blueprint for the Built Environment Industry [113], BuildSG Transformation Fund [114], Green Building Innovation Cluster Demonstration Program (GBIC-Demo) [115].
Quality Control	Building Research Establishment Environmental Assessment Method (BREEAM) [116].	Leadership in Energy and Environmental Design (LEED) [117].	Green Label Certification Program (GM:2021) [118], Green Mark Incentive Scheme (GMIS) [119].
Typical Cases	BedZED (2002) —A sustainable residential area in London, one of the pioneers of green buildings in the UK. —It uses a variety of innovative technologies such as solar energy, green roofs, and recycling water systems to reduce dependence on natural resources while improving the quality of life of residents [120].	Apple Park (2017) —One of the world's largest green office parks, covering an area of 175 acres. —Green features: relying on solar power generation, the building has a large amount of green space, a natural ventilation system, and energy-saving building materials. Environmental protection and employee well-being are the core [121].	Marina Bay Sands (2010) —It uses a variety of green construction technologies, combines luxury hotels, commercial and entertainment facilities, and is a model of green buildings. —Green features: including air conditioning systems, energy management systems, solar panels, rainwater collection systems, etc. It also optimizes natural ventilation through design to reduce dependence on air conditioning systems [122].

supervisory system that imposes economic penalties on polluters [100]. To advance sustainable waste management, the government has introduced a landfill tax to incentivize the reuse of solid waste [101]. Additionally, strategic investments in employment programs, capital deployment, and technological innovation further support national efforts to reduce carbon emissions [102]. Since the environmental movement of the 1960s, the United States has enacted a comprehensive suite of environmental regulations. To manage carbon emissions, the US proposed the “3550” carbon reduction target [103] and introduced a carbon tax on domestically produced carbon-intensive goods [104]. Air

quality management includes the establishment of national ambient air quality standards, while municipal solid waste management is supported by an integrated recycling system [105]. Singapore's green buildings achieve average energy cost savings and carbon emission reductions through systematic green certification programs [123]. The country has developed technical standards for recycled concrete products to enhance solid waste recycling [106]. Its long-term low-carbon strategies are outlined in the Singapore Green Plan 2030, which sets clear targets for sustainable development over the coming decade [107]. Additionally, the Long-Term Low Emissions Development Strategy commits to halving the country's peak carbon emissions by 2050 [108]. Complementing these efforts, Singapore has implemented a mandatory carbon tax across all sectors to stimulate the growth of its carbon market [109].

Technological innovation in green construction emphasizes achieving social, economic, and environmental benefits by promoting prefabrication technology and accelerating the adoption of intelligent systems. The UK integrates regional climate considerations into its technological applications [110]. To address its long cold winter issues, the insulation designs for walls, roofs, doors, and windows are utilized to enhance energy efficiency. Surrounded by the sea and subject to strong winds, the UK leverages the chimney effect to achieve indoor thermal comfort with minimal energy consumption. It also leads to offshore wind power, contributing to nearly half of global generation. Additionally, passive solar energy use is advanced into active systems for energy generation, supported by adaptive control and regulation technologies to address climate variability. The US has developed a mature market for prefabricated buildings, driven initially by the surge in housing demand during wartime. This led to the emergence of mobile “car houses”, which later evolved into rail-mounted houses [124]. With the development of construction industrialization, the United States has introduced a series of mandatory regulations such as the “Construction and Safety Standards for Prefabricated Houses” [111], integrating these standards into its industrialized construction framework. Since 2000, the United States has emphasized the adoption of digital construction technologies, including BIM [112]. Singapore, on the other hand, prioritizes the integration of the construction industry with advanced information technologies. It actively promotes the adoption of innovative solutions such as Design for Manufacturing and Assembly (DFMA), Integrated Digital Delivery (IDD), automation, and robotics [113]. These technologies have facilitated the development of integrated intelligent facility management systems. To accelerate technological innovation and enhance productivity, Singapore has introduced various incentive programs, including tax reductions and exemptions [114]. Additionally, the country has launched initiatives like the Green Building Innovation Cluster demonstration program, which promotes the adoption of innovative technologies through real-world demonstrations [115].

Quality supervision in green construction emphasizes meticulous planning, collaborative design, and strict adherence to current quality standards. The UK's BREEAM standard, the world's first green building assessment system, evaluates projects throughout their life cycle, from planning and design to operation and maintenance [116]. BREEAM assesses nine key aspects: energy consumption, health and livability, project green management, green building materials, pollution control, land use and ecology, waste management, green transportation, and water resource utilization. In contrast, the US LEED certification is the most widely adopted green building rating system globally [117]. LEED prioritizes environmental, social, and governance benefits, focusing on building decarbonization, environmental resilience, human health, equity, and ecosystems. It serves as a comprehensive guide for green building design and quality assurance. Similarly, Singapore's Green Mark certification promotes environmental friendliness and sustainability in new building projects [118]. It aims to enhance energy efficiency while incentivizing high standards through programs like GMIS-EB 2.0, offering cash or gross floor area (GFA) incentives to encourage excellence in implementation [119].

Currently, regions in China that have launched green construction pilot projects are experiencing a more substantial reduction in carbon dioxide emissions per unit of GDP compared to non-pilot regions. This indicates the effectiveness of policy-led pilot implementation in advancing low-carbon development. However, compared with developed countries, China still faces notable gaps in several key areas, including policy and regulatory frameworks, technological systems, and the demonstration and promotion of green construction practices [125]. To accelerate progress, China can draw valuable lessons from international best practices and focus on the following three strategic pathways: (1) Establishing a robust green construction policy system: It is essential to introduce mandatory standards and strengthen regulatory oversight to ensure effective policy implementation. At the same time, a diversified set of incentive mechanisms—such as financial rewards, subsidies, tax reductions, and exemptions—should be put in place to encourage stakeholder participation. Equally important is raising public awareness to address misconceptions regarding the feasibility and benefits of green construction; (2) Fostering technological innovation in green construction: Substantial investments in research funding and talent cultivation are needed to drive the development and deployment of advanced green construction technologies. In addition to creating new solutions, optimizing existing technologies to improve energy and resource efficiency is crucial. The integration of digital technologies—such as BIM, IoT, and AI—can further enhance coordination and innovation across the construction lifecycle; (3) Scaling up green construction demonstration projects: Priority should be given to establishing high-quality demonstration projects, especially those funded by the government, which can serve as replicable models for the broader industry. Policy support in the areas of finance, taxation, and urban planning should be aligned to offer targeted incentives, such as low-interest loans and special subsidies. A comprehensive pilot evaluation framework should also be established to

track project outcomes and continuously refine implementation practices for wider adoption.

Lessons from these countries underscore the importance of coupling regulatory tools with long-term incentives and digital integration. These insights are further used to inform the barrier identification and policy recommendations in Section 6. While these international experiences provide valuable insights, their applicability to China’s context faces significant limitations that must be carefully considered. Institutional transfer constraints arise from fundamental differences in governance structures, regulatory frameworks, and market mechanisms between China and these developed countries. Economic context limitations become apparent when considering the different stages of economic development, labor costs, and consumer purchasing power that affect technology adoption feasibility. Cultural and social barriers may limit the direct transfer of stakeholder engagement strategies and public participation models that work effectively in Western contexts. Technology adaptation challenges emerge when attempting to implement technologies designed for different climate conditions, building types, and urban planning approaches. Scale and speed constraints affect the applicability of approaches developed in smaller economies to China’s massive construction market and rapid urbanization pace. Future research should focus on developing culturally appropriate adaptation strategies, conducting pilot studies to test international technology transfer approaches, and creating hybrid models that combine international best practices with local innovations and institutional contexts.

Key barriers and strategic recommendations for advancing green construction in China

China’s green construction sector has seen considerable progress in recent years. However, the development process still encounters

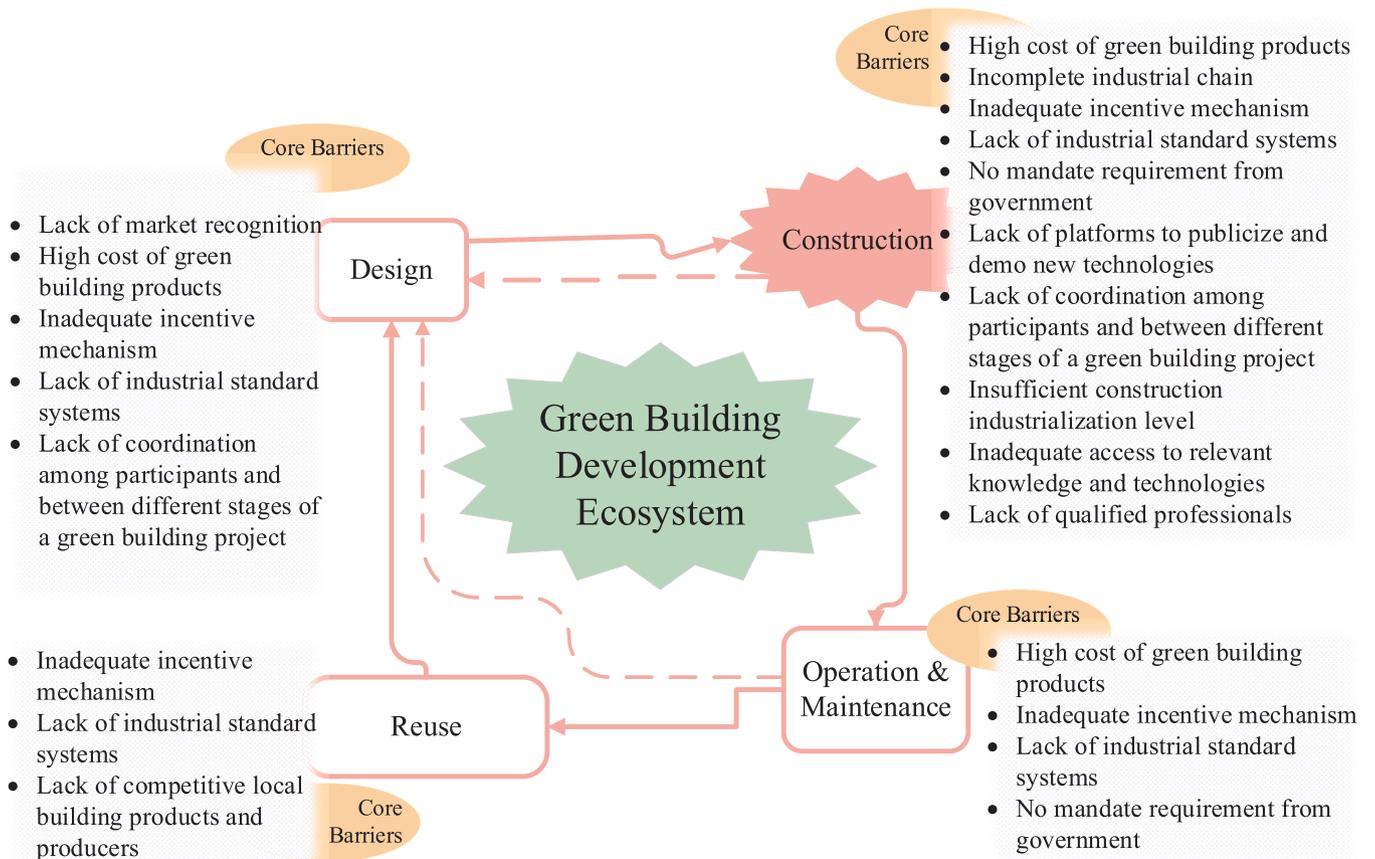


Fig. 7. Ecosystem of barriers to green building development throughout the building lifecycle [76].

substantial and multi-faceted challenges. These challenges span from technology and regulatory mechanisms to economic feasibility and public participation, and are closely tied to the complex lifecycle of green building projects.

This section provides a comprehensive analysis of key implementation barriers based on a combined approach of literature review and expert interviews. It then proposes a set of evidence-based policy recommendations tailored to address these barriers, offering a structured and stakeholder-related roadmap for enhancing the effectiveness of green construction policies in China.

Key implementation barriers

In recent years, China's green construction and its related industries have experienced rapid growth. However, there remain significant challenges throughout the sector, especially in areas such as project design, construction processes, technological integration, and soft skills related to regulations, management, and stakeholder incentives [7,126]. Summarizing the key barriers encountered throughout the life cycle of green buildings, as illustrated in Fig. 7 [76], it is evident that the green construction process faces numerous difficulties due to its involvement with multiple entities and industries. Consequently, the challenges in implementing green construction in China are multifaceted. The primary barrier factors at this stage can be categorized as immature technology, lack of administrative capacity, poor economics, and weak

Table 2
Categorized overview of key implementation barriers and representative evidence from the literature.

Ref.	Barrier description	Category
[129,130]	Lack of revolutionary scientific and technological innovations to meet green construction goals	Technology
	Fragmented regulations that hinder innovation and implementation	Administration
[127]	Limited public education on sustainability	Knowledge
	Absence of clear policy and industry guidance; weak governmental supervision	Administration
	Underdeveloped market environment; ineffective demonstrations; lack of reputational incentives	Economy
	Lack of green construction training and ecological awareness among stakeholders	Knowledge
[128,131,132]	Low public awareness of green construction	Knowledge
	Shortage of applicable green construction technologies	Technology
	Weak regulatory and incentive frameworks	Administration
	High initial costs for developing technologies and green materials	Economy
[133]	Higher residential development costs	Economy
	Consumers' reluctance to pay for green features	Knowledge, Economy
[134,135]	Stakeholder conflicts due to misaligned interests	Administration
[27]	Additional costs and extended project timelines due to green practices	Economy
	Lack of qualified green suppliers and regional disparities in green knowledge	Knowledge
[128]	Higher material costs; long planning cycles for new technologies; delays from unfamiliarity with green processes	Technology, Economy
[126]	High manufacturing and construction cost burdens	Economy
[136,137]	Insufficient capital investment; difficulty in accessing financial support	Economy
[25]	Increased project costs; high implementation costs for green practices	Economy
	Weak team communication and interest among project team members	Administration
	Lack of reliable research on green building benefits; Insufficient engagement from owners	Knowledge

public awareness and engagement [127,128]. Specific details of these barriers are presented in Table 2.

As illustrated in Table 2, and aligning with the comprehensive analysis of existing studies and the preceding examination of the progress in implementing China's green construction policies, the prevalent barriers and their respective manifestations can be organized, as depicted in Fig. 8. This categorization serves to establish a barrier framework, enabling a systematic assessment of these barriers and the formulation of precise improvement strategies [138].

Analysis of expert interviews: refining and prioritizing barriers

The literature review identified numerous barriers to promoting green construction. To refine these findings and highlight key barriers, interviews were conducted with nine experts, each of whom had over a decade of experience in green construction research or practice. These participants included three professors specializing in building energy and environmental engineering, three government officials from the Green Construction Association, and three corporate executives involved in green construction projects. This cross-sectoral composition ensured comprehensive coverage of perspectives from academia, government, and industry.

The Delphi method was employed to rank the relative importance of each barrier, and the results are presented in Table A-3 (Appendix A). Based on the analysis, the challenges in promoting green construction can be grouped into three levels. At the most critical level are systemic barriers such as imperfect laws and regulations, ineffective green management, inadequate green construction evaluation system, and insufficient government incentives. These foundational issues hinder the alignment and accountability required for large-scale adoption. Secondary challenges include operational and institutional weaknesses such as poor supervision of policy implementation, a fragmented project management model separating design and construction phases, weak government leadership, high upfront costs for enterprises, limited investment and financing mechanisms, and a shortage of skilled professionals. These factors contribute to inefficiencies and discourage stakeholder participation in green construction initiatives. At the tertiary level, cultural and technological barriers further impede progress. These include low public acceptance, insufficient attention to fostering a green construction culture, lack of short-term profitability, immature technical systems, limited technology dissemination, and underdeveloped ethical principles for sustainable human settlements.

To address these layered and interconnected challenges, the interviewed experts recommended government incentive policies such as financial subsidies, tax exemptions, and priority approvals to encourage industry participation. A critical factor is the project planning phase, which shapes the project's direction, including the selection of appropriate green technologies and materials. For instance, using high-performance thermal insulation materials can significantly enhance building energy efficiency and reduce consumption. From a technological and managerial perspective, experts highlight the importance of BIM for fostering collaboration and minimizing errors, as well as adopting prefabrication and modular construction to improve efficiency. Comprehensive strategies are needed, including policy-driven guidance, government funding support, professional training programs, public awareness campaigns, and increased investment in green technology research and development. Additionally, preferential policies to attract private sector investment are crucial for sustaining long-term growth in the green construction sector. By addressing these multifaceted challenges with a combination of policy measures, technological innovation, and cultural transformation, the green construction sector can achieve sustainable growth and greater societal acceptance. These expert insights provide a direct linkage to the policy recommendations developed in Section 6.2, ensuring that the identified barriers are matched with targeted solutions.

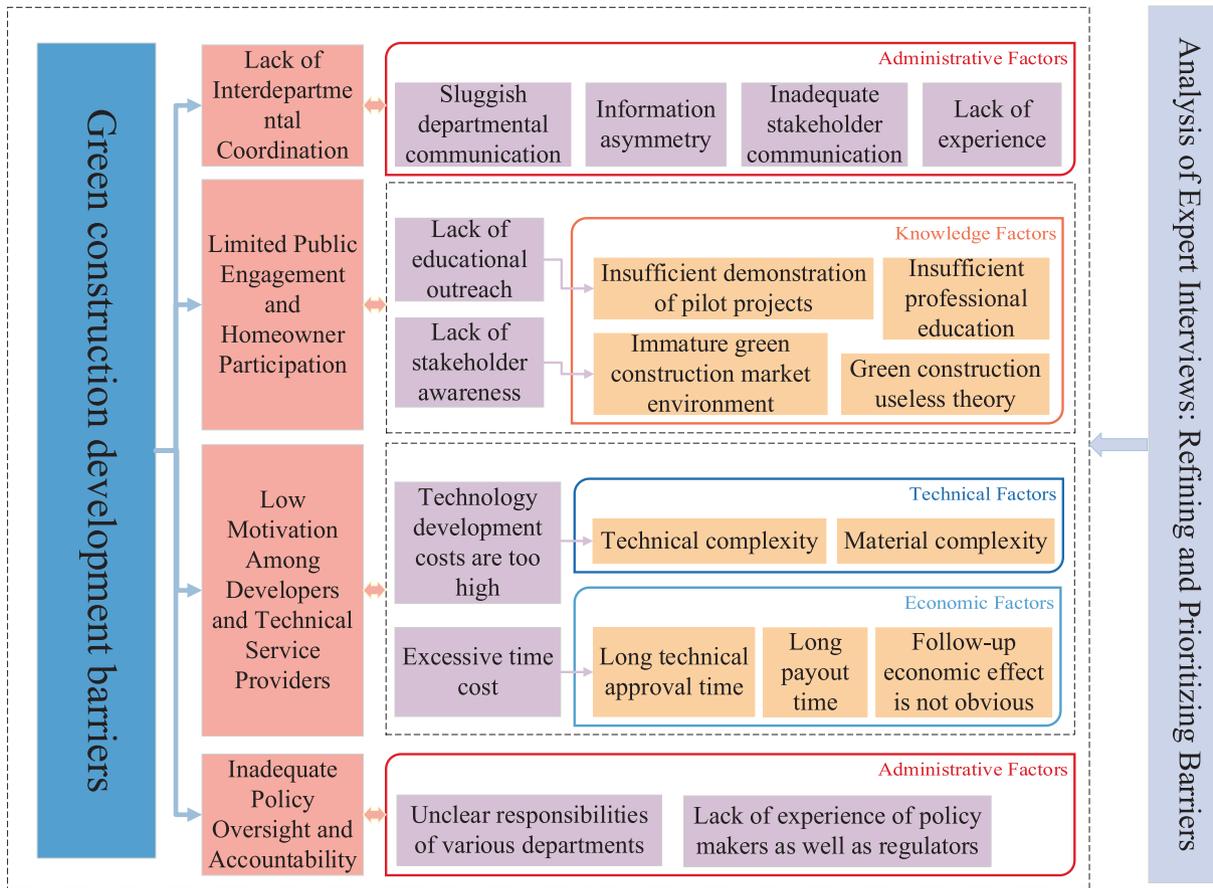


Fig. 8. Framework of key barriers to green construction development.

Lack of interdepartmental coordination

Green construction inherently spans multiple domains, including green planning, sustainable design, low-carbon construction techniques, and environmentally friendly material usage. As such, it requires coordination among several government bodies—namely, those overseeing housing, urban development, finance, technology, and environmental regulation. However, the current policy landscape often overlooks interdepartmental synergy, resulting in redundant efforts, conflicting responsibilities, and inefficient information sharing [139]. According to Yau [140], the study pointed out that the information asymmetry around green buildings among different stakeholders, and the lack of timely communication among various personnel led to information deviation, thus affecting the progress of construction work. Currently, China’s promotion of green construction is still dominated by government intervention [141,142], with insufficient market participation and enthusiasm [143]. Moreover, there is a prevalent division of responsibilities among different government departments, impeding effective communication. This division inflates costs, diminishing motivation to implement green construction practices. Conflicting interests among stakeholders further exacerbate the challenge, introducing uncertainty and eroding trust relationships, making effective cross-sectoral communication a considerable challenge [144,145]. Additionally, varying levels of expertise among supervisory staff across departments hinder the smooth implementation of green construction initiatives.

Given these limitations, it is imperative to promote mandatory cross-sector collaboration frameworks. Establishing interdepartmental coordinating mechanisms, joint project oversight platforms, and unified digital reporting systems can facilitate more coherent and efficient policy implementation.

Limited public engagement and homeowner participation

Despite the introduction of various incentive policies at both national and local levels, the impact of these initiatives remains limited—largely due to the insufficient willingness of homeowners to actively participate in green construction efforts [146]. Wu et al. [127] identified the underdeveloped market environment as a key constraint to the advancement of green buildings in China, which in turn hinders the broader promotion of green construction. Liu and Hu [147] further pointed out that green construction remains in its infancy, particularly due to the public’s limited awareness. This situation is especially common in developing countries, where the green construction market is still in its exploratory stage [148].

While awareness of green construction has gradually increased in economically advanced first-tier cities—where developers and contractors are more inclined to adopt sustainable practices under policy guidance [149]—the overall level of public understanding and engagement, particularly among homeowners, remains weak [150]. In most regions, homeowners rarely consider whether their dwellings meet green building standards or whether green construction techniques have

been employed [151]. This knowledge gap diminishes the effectiveness of energy-saving measures during the operational phase of buildings.

Moreover, green buildings are often perceived as expensive and inaccessible, further dampening public acceptance [152,153]. A lack of targeted education, training programs, and effective promotional efforts exacerbates this issue [154]. However, empirical evidence suggests that awareness campaigns and educational initiatives can positively influence market behavior and increase demand for green construction [155]. To support the long-term growth of green construction in China, it is imperative to strengthen public education and targeted outreach, especially among homeowners, to shift perceptions, foster behavioral change, and build a more informed and engaged consumer base [156].

Low motivation among developers and technical service providers

The underdevelopment of green construction's industry chain has led to relatively higher costs and more complex management requirements compared to traditional construction practices. Furthermore, the strong focus on cost control and short-term profitability among most developers and technical service providers has led to low motivation to engage in green construction [26]. As demonstrated by Abidin [157], knowledge, awareness, and understanding of the environmental and economic consequences of one's actions are critical determinants of the willingness to adopt sustainable construction practices. Thus, a lack of awareness and understanding among these key stakeholders significantly hampers the transition toward greener practices.

Green construction often involves more advanced technologies, novel materials, and integrated processes compared to traditional construction approaches [25,158]. If not well managed, this added complexity can disrupt construction workflows and negatively affect project outcomes, further discouraging participation. Moreover, green construction technologies and products typically require multi-party testing and validation, which slows down technical research and development and delays the provision of adequate technical support from service providers [158]. Similarly, Zhang et al. [128] and Eisenberg et al. [159] observed that green construction projects tend to require longer completion periods than their conventional counterparts. These extended timelines increase overall project costs and reduce the willingness of developers and service providers to adopt green methods. Compounding the issue, green construction tends to offer long-term environmental benefits but limited immediate financial returns, making it less attractive to stakeholders focused on short-term gains.

One of the most critical constraints is insufficient and unstable financing. Despite the availability of some market-based and governmental financial mechanisms—such as subsidies, low-interest loans, tax incentives, and dedicated funds—support remains inadequate [160]. The required high upfront investment, coupled with extended payback periods and high performance uncertainty, significantly increases perceived risk. These risks are further exacerbated by the lack of accessible information on funding opportunities, cumbersome application procedures, and limited transparency in financing channels. In addition, many cities do not maintain publicly available energy consumption data for buildings, making it difficult to quantitatively assess returns on green construction investments and secure financing [161].

In summary, low awareness, technical complexity, uncertain returns, and financial barriers collectively undermine the enthusiasm of developers and service providers to actively engage in the green construction market. These interrelated challenges highlight the need for targeted incentives, streamlined financial access, and greater capacity building across the industry.

Inadequate policy oversight and accountability

One of the most critical barriers to the advancement of green construction in China is the lack of strong policy oversight and clearly defined industry guidance. In particular, administrative fragmentation and weak regulatory enforcement continue to hinder the development of

low-carbon construction practices [127,162]. At present, the division of responsibilities among stakeholders involved in green construction remains ambiguous. The absence of a well-established accountability framework—coupled with inadequate legal and regulatory support—has significantly constrained the implementation and diffusion of green construction initiatives.

In many cases, stakeholders are reluctant to pursue green construction due to the perception of high initial costs and unclear regulatory expectations. Without robust government supervision, clear incentives, and binding obligations, it becomes difficult to align stakeholder behavior with long-term sustainability goals. As highlighted by [36], the government must move beyond passive policy formulation and take a more active role in enforcing, incentivizing, and monitoring green construction practices.

Crucially, policy oversight should not be limited to the publication of guidelines and administrative regulations. It must also involve the development of measurable evaluation criteria and effective monitoring mechanisms that can track policy implementation, ensure compliance, and adjust interventions based on performance outcomes [163]. The absence of such dynamic evaluation frameworks reduces the capacity to enforce green standards consistently across regions and projects.

Furthermore, the lack of communication and collaboration among various government departments exacerbates implementation challenges. Different ministries and agencies often operate in silos, with limited information-sharing or coordinated decision-making processes. This institutional fragmentation weakens policy coherence and contributes to duplicated efforts or contradictory measures. At the same time, many stakeholders—including local authorities, developers, and contractors—lack adequate awareness and understanding of existing green construction regulations, further weakening compliance and enforcement.

Taken together, these issues form a systemic barrier to the high-quality and large-scale development of green construction. Without stronger oversight mechanisms, clearly assigned responsibilities, and a unified regulatory framework, the current trajectory of green construction in China risks falling short of its long-term goals. Strengthening governance capacity, building cross-sectoral coordination platforms, and institutionalizing performance-based accountability will be essential for overcoming these deeply rooted barriers.

Strategic recommendations to overcome implementation barriers

While national and local governments in China have introduced a series of supportive policies to promote green construction, the current frameworks remain fragmented and underdeveloped. Persistent challenges in policy consistency, technical capacity, financial accessibility, professional development, and public participation continue to impede widespread adoption. Building on the multi-dimensional barriers identified in Section 6.1, this section presents targeted strategic recommendations to address these bottlenecks and construct an integrated pathway toward sustainable green construction. A roadmap summarizing the key strategies is illustrated in Fig. 9.

Establishing a comprehensive assessment and certification system

One of the most critical barriers to promoting green construction is the lack of a dedicated and reliable performance evaluation system, particularly one that accounts for the full spectrum of environmental, technical, and managerial dimensions specific to construction processes [164]. As the green construction sector remains in its early developmental stage, current assessment standards are often fragmented or overly reliant on conventional green building evaluation frameworks [165]. Given that green construction represents production and implementation phase of green buildings, rather than the final product itself, existing evaluation systems designed for completed buildings can only be partially applied. It is therefore essential to develop a tailored and process-oriented assessment system, which not only draws from existing

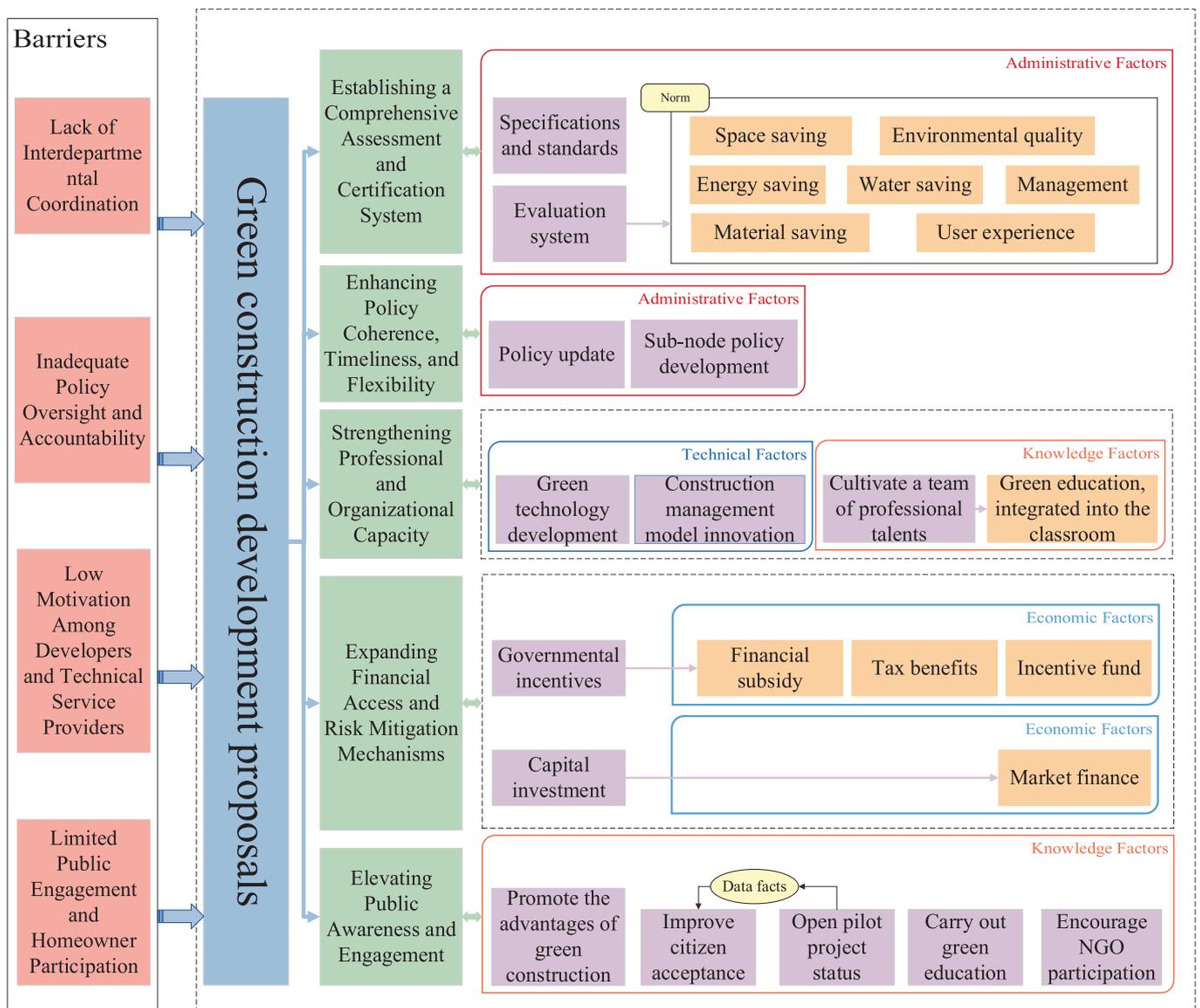


Fig. 9. Roadmap of policy-driven strategies for advancing green construction in China.

green building metrics but also incorporates indicators specific to the construction phase, such as material usage efficiency, site energy performance, emission control during construction, and waste reduction practices.

Notably, China’s current green building evaluation framework includes six major subsystems: space-saving, energy-saving, water-saving, material-saving, indoor environmental quality, and operational management [126]. While these provide a strong foundation, a green construction evaluation system must go further by incorporating additional dimensions such as construction time efficiency, digitalization (e.g., BIM application), prefabrication rates, construction worker well-being, and user experience metrics to assess post-construction satisfaction and comfort. Furthermore, it is advisable to expand the application of advanced green construction standards, including performance-based and lifecycle-oriented benchmarks [166,167]. The establishment of a nationally recognized certification framework—aligned with sustainable design principles, carbon-neutral goals, and industrial modernization standards—can significantly regulate project behavior during the construction phase. Such a framework would enhance transparency, standardize practices across regions, and ensure the scalability of green

construction initiatives [168]. Ultimately, a comprehensive and multi-dimensional evaluation and certification system is not only a technical necessity but also a strategic tool for guiding stakeholder behavior, encouraging innovation, and ensuring the high-quality delivery of green construction projects nationwide.

However, establishing comprehensive assessment systems faces methodological complexity constraints in developing indicators that accurately capture diverse regional conditions and building types. Implementation cost limitations may restrict the adoption of sophisticated evaluation frameworks, particularly in resource-constrained regions. Standardization challenges arise when attempting to balance national consistency with local adaptation needs.

Enhancing policy coherence, timeliness, and flexibility

Consistency and currency issues with green construction policies in China have been highlighted by many researchers [69]. Li and Shui [169] emphasized that inconsistency might confuse stakeholders about policy tools, while outdated policies could impede the adoption of advanced technologies. Although government departments have crafted policies based on the characteristics of green construction development,

the effectiveness of these policies might diminish or even have adverse effects due to market uncertainty and variability in the practice process during policy formulation and implementation [21]. Additionally, many relevant policies in China are mandatory and lack market flexibility [69,170].

A critical concern in the green construction market regarding new incentives is their stability and sustainability. Drawing from the experience of green building policies, it is essential to design green construction incentives with long-term viability in mind [171]. One effective approach could involve implementing incentives in stages, such as providing incremental rebates during the design process, delivery, one year after delivery, and three years after delivery [171].

In summary, the design of long-term green construction incentives proves more effective in promoting green construction. Concerning environmental protection, Choi [172] contended that green building incentives were usually most effective at the local level. Hence, by drawing from green building policy research, green construction incentive policies can also be developed at the local level. Furthermore, given the varying levels of development across regions, local governments can tailor green construction incentives to their level of development, especially considering that the scope of incentives and implementation flexibility can differ among jurisdictions [173]. Achieving coherence, timeliness, and flexibility in green construction policy requires a multi-tiered governance model, combining strong national guidance with local experimentation, dynamic incentive structuring, and continuous policy renewal to match evolving technological and market contexts.

Strengthening professional and organizational capacity

Achieving high-quality, long-term development in green construction fundamentally depends on technological competence, specialized knowledge, and a skilled workforce. Numerous studies have underscored that the presence of experienced professionals—particularly those familiar with green construction techniques—is a critical success factor in ensuring effective project delivery. For instance, prior research has identified that contractors employing professionals with direct experience in green construction projects, and those who actively recruit green building experts, are significantly more likely to succeed in implementing sustainable practices [174]. Similarly, Lam [175] emphasized that the core competency of green construction projects lies in the depth of green technology expertise embedded within the project team.

Moreover, capacity building must go beyond industry practice and extend into the educational ecosystem. University-level environmental and sustainability education plays a pivotal role in shaping future professionals capable of addressing the complex challenges associated with sustainable urbanization and low-carbon construction [176]. The concepts of “green universities” and “green education” have been widely promoted over the past two decades [177,178], aiming to cultivate environmental awareness and practical skills among students. Evidence suggests that developing green-oriented curricula not only enhances student knowledge of sustainability issues but also contributes to broader socio-economic transitions toward greener development models [179,180].

To foster a strong professional and organizational foundation for green construction, several strategic measures are essential. These include the formulation of targeted vocational and professional training policies, the establishment of national and regional talent pools, and the expansion of green construction programs and certifications in higher education institutions. Simultaneously, cross-sectoral research collaboration—particularly between academia, industry, and government—should be encouraged to accelerate knowledge transfer and

technological innovation.

Finally, it is crucial to improve interdepartmental coordination mechanisms to ensure that professionals working across different phases of the construction lifecycle—design, procurement, construction, and evaluation—can effectively collaborate. This integrated approach will not only boost organizational efficiency, but also enhance the adaptability and resilience of the green construction industry in the face of evolving environmental and policy challenges.

Expanding financial access and risk mitigation mechanisms

In the current landscape, green construction projects require substantial capital investments due to their long investment cycles and delayed returns. Adequate financial input is essential for implementing policy measures, supporting technological research, and promoting professional training and public awareness initiatives [160,181]. As such, financial allocation has become a foundational prerequisite for the large-scale promotion of green buildings. However, the shortage of effective and accessible funding remains a key barrier to the widespread adoption of green construction [137,182].

To overcome this challenge, well-structured and evidence-based financial incentives—such as subsidies, tax relief, and dedicated green funds—are needed to mitigate the high upfront costs, reduce investment risks, and improve the financial feasibility of green construction projects [183]. These measures can help alleviate the economic burden on stakeholders, attract private capital, and stimulate market participation [184]. Establishing a transparent, stable, and scalable financial support system is therefore critical to accelerating the growth of the green construction industry in China [185].

At the policy level, it is vital to strengthen macro-level financial regulation and continuously improve relevant green construction policies. Governments should prioritize support for pilot projects and explore innovative mechanisms to integrate financial resources across multiple sectors. In particular, regional authorities should increase public investment to support enterprises in developing green technologies and solutions.

Moreover, efforts should be made to leverage social capital by facilitating partnerships with private investors and financial institutions. This includes promoting co-financing models, streamlining application procedures for subsidies and loans, and providing matching funds to lower financial barriers. By doing so, a more inclusive and resilient financial environment can be cultivated to support the high-quality and sustainable development of green construction across China.

Elevating public awareness and engagement

With growing concerns over global warming and the increasing frequency of climate-related disasters, public support for sustainable construction practices is on the rise [186]. A critical factor in advancing green construction lies in public acceptance and active engagement. As noted by Fu et al. [187], the public plays a dual role—not only as recipients of policy outcomes but also as key influencers shaping environmental behavior and policy implementation.

Consumer preference for green products and environmentally friendly lifestyles creates market-driven pressure on developers and construction firms to adopt more sustainable practices. To capitalize on this trend, both governments and enterprises must invest in targeted public education campaigns that communicate the concrete benefits of green construction compared to conventional approaches. Enhancing public understanding of measurable outcomes—such as reduced energy bills, improved indoor comfort, and long-term environmental gains—is essential to increasing social buy-in.

Transparency in project planning and execution also plays a pivotal role in building public trust and legitimacy. Open access to performance

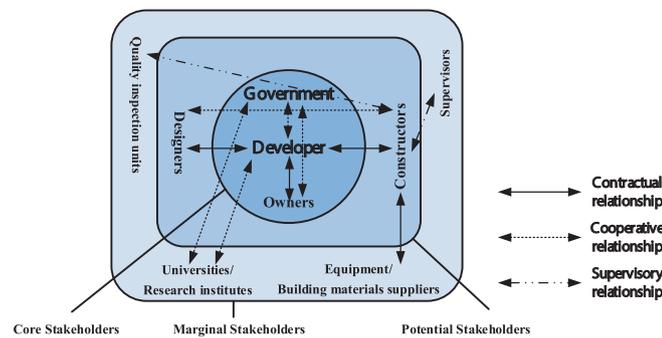


Fig. 10. Interactions and roles of key stakeholders in the green construction ecosystem.

data, independent certifications, and participatory planning processes can improve societal confidence in green construction initiatives. In parallel, collaboration with local stakeholders—such as NGOs, professional associations, and community organizations—can broaden outreach and deepen citizen involvement.

In conclusion, a multi-channel communication strategy that combines media outreach, stakeholder engagement, and visible demonstration projects is vital to cultivating public awareness. Mobilizing the influence of industry champions and civil society can amplify educational efforts, showcase best practices, and foster a cultural shift toward sustainability. Ultimately, strengthening public engagement is indispensable for mainstreaming green construction and accelerating its integration into everyday urban development.

Stakeholder-based implementation strategies for green construction

Stakeholders are central to the successful promotion and implementation of green construction. Their diverse roles, interests, and influence levels shape decision-making across the entire lifecycle of a project. As green construction involves interdisciplinary integration and multi-agent participation, effectively engaging stakeholders is critical to ensuring smooth project execution and achieving sustainability goals.

Drawing upon both literature review and expert interviews, this study identifies key stakeholders in green construction, including government agencies, developers, design firms, construction contractors, supervision bodies, and material suppliers. A Likert scale was employed to evaluate the significance of each stakeholder, where scores of “1”, “2”, and “3” represented “unimportant”, “moderately important”, and “very important”, respectively. Based on these scores, interest groups were categorized into core, potential, and peripheral stakeholders [188]. Among these, the government and developers emerged as core actors, given their high levels of power, legitimacy, and urgency, as shown in Table A-4 (Appendix A).

According to stakeholder theory and the practical realities of China’s green construction landscape, the interactions among stakeholders form a dynamic and interdependent network. As shown in Fig. 10, each stakeholder plays a distinct yet complementary role. For instance, the government plays a role in policy guidance and supervision, and promotes the implementation of green construction by formulating relevant laws, policies and technical standards. Enterprises, particularly developers and contractors, are the primary agents of implementation, responsible for integrating green technologies, materials, and practices throughout the project lifecycle. Research institutions, particularly developers and contractors, are the primary agents of implementation, responsible for integrating green technologies, materials, and practices throughout the project lifecycle. The social parties, including non-governmental organizations and the public, jointly create a social atmosphere that supports green construction by participating in the publicity, education, and market promotion of green construction.

The interaction among these actors is mutually reinforcing. For instance, the government supports green initiatives through planning guidance, fiscal subsidies, and public campaigns, while also building green public infrastructure (e.g., energy-efficient housing and transit systems). Simultaneously, public recognition and feedback provide essential insights that inform government policy refinement and regulatory adjustments. This feedback loop enhances accountability and continuous improvement in green construction practices.

From a project management perspective, the life cycle of green construction can be divided into three major stages: planning, design, and construction. In the planning stage, government departments review and approve projects proposed by developers. Through regulatory frameworks and incentive mechanisms, authorities guide developers’ decisions on project viability and sustainability targets. During the design stage, architectural and engineering teams translate these expectations into construction drawings and specifications that meet both regulatory and technical standards. In the construction stage, contractors coordinate with designers, suppliers, and supervision units to implement the plans, ensuring quality control and compliance. Supervisory bodies monitor progress and validate performance outcomes.

To enhance project effectiveness and green outcomes, it is essential to increase alignment among stakeholders, improve coordination across institutional boundaries, and introduce shared incentives. In particular, developers and government entities must work together to stimulate consumer interest, for example by offering rebates for energy-efficient homes or promoting awareness of long-term cost savings. Ultimately, stakeholder-based implementation strategies should be tailored, coordinated, and iterative, recognizing the diverse motivations and capabilities of actors involved. By strengthening stakeholder collaboration, fostering mutual accountability, and embedding green values into each stage of the project cycle, China can accelerate the transition to sustainable construction practices on a national scale.

Future perspectives and research directions

The comprehensive analysis of China’s green construction policy frameworks and implementation barriers reveals both significant progress and persistent challenges that shape the trajectory of future research and development. As China continues its transition toward carbon neutrality, several critical areas emerge where technological innovations, policy refinements, and methodological advances can address the identified barriers while building upon successful pilot experiences.

The interdepartmental coordination challenges identified in this study highlight the urgent need for integrated governance mechanisms that transcend traditional administrative boundaries. Future research should focus on developing adaptive policy frameworks that can accommodate the rapid pace of technological change while maintaining coherence across the six policy dimensions identified in our analysis.

Technological innovation represents perhaps the most promising avenue for addressing the cost and performance barriers consistently identified by stakeholders. The integration of digital technologies, particularly Building Information Modeling (BIM) and Internet of Things (IoT) systems, offers significant potential for enhancing project coordination and real-time performance monitoring. These technologies can address the policy oversight challenges revealed in our analysis while providing the data foundation necessary for evidence-based policy refinement. Advanced prefabrication techniques, building upon the success observed in pilot regions, could further reduce construction timelines and improve quality control while addressing labor shortage concerns that increasingly affect the construction industry.

The development of new materials presents another critical frontier for green construction advancement. Bio-based materials utilizing agricultural waste and locally sourced renewable resources could simultaneously address cost concerns and environmental objectives while supporting rural economic development. Smart materials with

adaptive thermal properties and self-monitoring capabilities could enhance building performance while reducing operational costs, directly addressing the lifecycle cost barriers identified in our stakeholder analysis. These material innovations require substantial research investment but offer the potential for transformative improvements in both environmental performance and economic viability.

Financial innovation emerges as equally important given the persistent cost barriers identified across multiple stakeholder groups. Performance-based financing models that reward measurable environmental outcomes could align investor interests with sustainability objectives while reducing upfront cost burdens. Green bonds and other innovative financing mechanisms specifically designed for construction projects could provide the capital mobilization necessary for large-scale implementation. Risk-sharing mechanisms between public and private sectors, building upon the pilot project model, could facilitate broader adoption while maintaining quality standards.

The stakeholder engagement challenges revealed in our analysis point toward the need for more sophisticated approaches to public participation and professional capacity building. Digital platforms that facilitate transparent communication among diverse stakeholder groups could address coordination problems while building public trust in green construction initiatives. Targeted education programs that address specific knowledge gaps identified among different professional groups could enhance implementation capacity while promoting innovation adoption.

The integration of green construction with broader urban sustainability initiatives offers substantial potential for synergistic effects. Climate adaptation strategies that incorporate green construction principles could enhance urban resilience while contributing to carbon neutrality objectives. Circular economy approaches that integrate construction waste management with material production could reduce environmental impacts while creating new economic opportunities. These integrated approaches require interdisciplinary research that spans urban planning, environmental science, and construction management.

Conclusion

Green construction, strongly advocated by the Chinese government, is a critical pillar in the high-quality development of China's economy and the transformation of urban and rural construction. Its potential to enhance energy efficiency and reduce carbon emissions in buildings makes it a key contributor to the global carbon-neutral agenda. However, there is limited research on green construction policy incentives, particularly critical reviews from diverse perspectives. This paper offers a comprehensive and critical analysis of green construction policy incentives, providing an innovative summary of China's national and local policies. It draws on international policies and practical experiences to inform China's policymaking. Additionally, this study employs expert interviews and Delphi methods to refine the literature analysis findings and highlight core factors, to identify key barriers and propose practical recommendations for stakeholders.

Green construction signifies the transformation and upgrade of China's construction sector, driven by the government's prioritization, and it holds inevitability and feasibility under new circumstances. The Chinese government has already set in motion various policies at national and local levels to propel green construction development. Policies related to pilots have effectively laid the foundation for a green construction model, offering valuable insights for the expansion of green construction in other regions. However, barriers such as inter-departmental communication gaps, lack of government funding support, weak green awareness among citizens, insufficient support and

collaboration, and inadequate innovation pose challenges. The pace of green technology development also struggles to keep up with industrial development requirements.

To surmount these barriers, this paper proposes targeted recommendations in alignment with China's national context. On the administrative front, the government should expedite policy updates and elucidations to enhance timeliness. Increasing regulation and offering incentives for communication and collaboration across various sectors are imperative. Economically, the government should introduce financial incentives and encourage private investment to bolster green construction. In terms of knowledge and information dissemination, the industry should prioritize transparency regarding project implementation and elevate citizen's awareness through diverse publicity channels. Technically, promoting education is essential to cultivate professional talent.

These recommendations, aligned with China's national policies, can establish a circular framework for implementing green construction. In this framework, the government drives industry action, the industry fosters public participation, and the public provides feedback to the government. The findings of this research offer guidance for enacting relevant laws and regulations, propose a blueprint for addressing barriers to green construction, and suggest forward-looking perspectives for future studies in the field. However, every policy has both benefits and drawbacks. While green construction policies can support government decision-making, incentivize corporate implementation, provide a foundation for scientific research, and raise public awareness, they also come with limitations. Such policies may consume significant national resources and impact public well-being. Poorly implemented policies risk creating governance issues, public dissatisfaction, social instability, and market inefficiencies. Therefore, future research should therefore incorporate analyses of potential negative impacts to ensure a more comprehensive evaluation of policy tools and their implications.

About the limitation of this study, while we have made concerted efforts to minimize potential biases in this study, there are inherent limitations that must be acknowledged. These include the reliance on secondary sources and expert interviews, which, while valuable, may not fully capture the perspectives of all stakeholders involved in green construction. Future research could address these limitations by incorporating a broader range of primary data, including case studies, quantitative assessments, and more diverse stakeholder interviews. Additionally, further exploration of regional variations and contextual factors could provide a more nuanced understanding of how policy frameworks and barriers may differ across regions. By expanding the scope of data sources, future studies could offer deeper insights into the challenges and opportunities for green construction policies.

CRediT authorship contribution statement

Zhengxuan Liu: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lin Zhou:** Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation. **Queena K Qian:** Supervision, Methodology, Investigation. **Henk Visscher:** Supervision, Methodology, Investigation. **Guoqiang Zhang:** Supervision, Methodology, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Table A-1
Summary of official policy websites used in this study.

Websites	Abbreviation	Links
China Policy Network	CPN	http://www.chinapolicy.net/ https://www.gov.cn/zhengce/index.htm
Ministry of Housing and Urban-Rural Development	MOHURD	https://www.mohurd.gov.cn/
Chinese Government Network	CGN	https://www.gov.cn/
China Daily	/	https://www.chinadaily.com.cn/
People's Daily	/	https://en.people.cn/
Xinhua News Agency	XNA	https://www.xinhuanet.com/

Note: Provincial and municipal government websites are not listed individually. The specific sources of policy content are referenced within the relevant sections of the paper.

Table A-2
Key policy initiatives in selected green construction pilot cities.

Pilot city	Key policy initiatives
Hunan Province	i) Strengthened leadership coordination; ii) The development of work programs, clear objectives, and tasks; iii) Strengthening regulatory support, improving institutional safeguards; iv) Financial support policies; v) The formation of expert teams, strengthen technical support.
Changzhou, Jiangsu Province	i) The URA organized various units to start the “Green Construction Evaluation Methodology Research” project; ii) Departments to do their part and cooperate fully; iii) Establishing an expert group to carry out technical guidance and evaluation; iv) Establishing a joint meeting system to promote and strengthen policy research; v) Strengthening technical system research and accelerate the introduction of evaluation standards for pilot projects.
Shenzhen, Guangdong Province	i) In-depth implementation of the ‘Shenzhen Special Economic Zone Green Building Regulations’; ii) Coordinating and promoting the works of carbon peak in construction; iii) Strong technical and platform support systems.

Note: The above information comes from the Hunan Provincial Department of Housing and Construction (<https://zjt.hunan.gov.cn/>), Changzhou Municipal People’s Government (<https://www.changzhou.gov.cn/>), Shenzhen Special Zone Newspaper (<https://sztqb.sznews.com/>).

Table A-3
Expert Delphi scoring of key barriers to green construction.

	Scientific researchers	Government workers	Business workers
Most important factor (5 points)	Lack of effective supervision on policy implementation; The government’s leading role is not strong enough.	Laws and regulations are imperfect, and green management is in name only; The green construction evaluation system is imperfect; The government’s incentives are insufficient.	Laws and regulations are imperfect, and green management is in name only; Enterprises have high-cost input and insufficient investment and financing.
Relatively important factor (4 points)	Imperfect laws and regulations, green management is in name only; The green construction evaluation system is imperfect; Lack of professional talents; The engineering management model of separation of design and construction; Low public acceptance; Not paying attention to green construction, lack of green construction culture.	Lack of effective supervision on policy implementation; Engineering management model with separation of design and construction.	The green construction evaluation system is imperfect; The initial risk is high; The technical system is immature and the technology has not been widely implemented; The engineering management model of separation of design and construction.
Generally important factor (3 points)	The government’s incentives are insufficient; The ethical concept of human settlement environment has not yet been formed.	The enterprise has high-cost investment and insufficient investment and financing; Insufficient profits in the short term; Lack of professional talents.	Lack of effective supervision on policy implementation; The government’s leading role is not strong enough; The government’s incentives are not enough; Green measures will affect progress; Insufficient profits in the short term; Technological innovation needs to be strengthened; Lack of professional talents; High cost and difficulty in technology research and development; Low public acceptance; Not paying attention to green construction, lack of green construction culture; Has not yet formed an ethical view of the human settlement environment.
Less important factor (2 points)	High initial risk; High enterprise cost investment and insufficient investment and financing; Insufficient profits in the short term; Immature technical systems and technology not widely implemented; Lack of pilot demonstration and guidance.	The leading role of the government is not strong enough; Green measures will affect the progress; Technological innovation needs to be strengthened; The technological system is immature and the technology has not been widely implemented; The cost of technology research and development is high and difficult;	/

(continued on next page)

Table A-3 (continued)

	Scientific researchers	Government workers	Business workers
Least important factor (1 point)	Greening measures will affect progress; Technological innovation needs to be strengthened; Technological research and development costs are high and difficult.	Lack of pilot demonstration and guidance; Low public acceptance; Not paying attention to green construction and lack of green construction culture; The ethical concept of human settlement environment has not yet been formed. High initial risk.	Lack of pilot demonstration and guidance.
Weight ranking	①(imperfect laws and regulations, green management is in name only) > ② (imperfect green construction evaluation system = insufficient government incentives) > ③ (lack of effective supervision of policy implementation = engineering management model with separation of design and construction) > ④ (insufficient government leadership = high enterprise cost investment, insufficient investment and financing = lack of professional talents) > ⑤ (low public acceptance = lack of attention to green construction, lack of green construction culture) > ⑥ (lack of short-term profits = immature technical system, technology not widely implemented = no ethical view of human settlement environment) > ⑦ (high initial risk) > ⑧ (greening measures will affect progress = technological innovation needs to be strengthened = high cost and difficulty of technology research and development) > ⑨ lack of pilot demonstration guidance.		

Table A.4 Stakeholder classification based on influence and importance.

Stakeholders	Score	Category	Scope definition
Government	2.5	Core Stakeholders	>=2.4, core stakeholders;
Developers	2.6	Core Stakeholders	>=1.8, potential stakeholders;
Owners	2	Potential Stakeholders	<1.8, marginal stakeholders;
Designers	2.3	Potential Stakeholders	
Constructors	2.0	Potential Stakeholders	
Supervisors	1.0	Marginal Stakeholders	
Equipment/building materials suppliers	1.0	Marginal Stakeholders	
Quality inspection units	1.0	Marginal Stakeholders	
Universities/research institutes	1.0	Marginal Stakeholders	

Appendix B

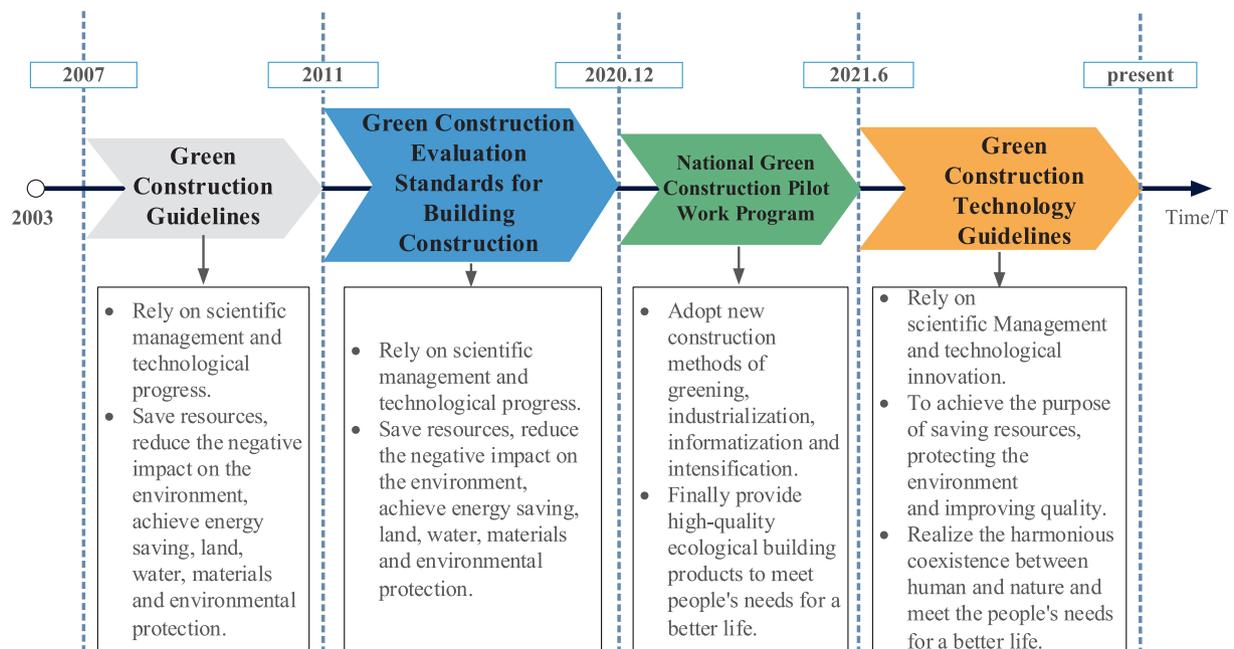


Fig. B-1. Evolution diagram of the green construction concepts with time.

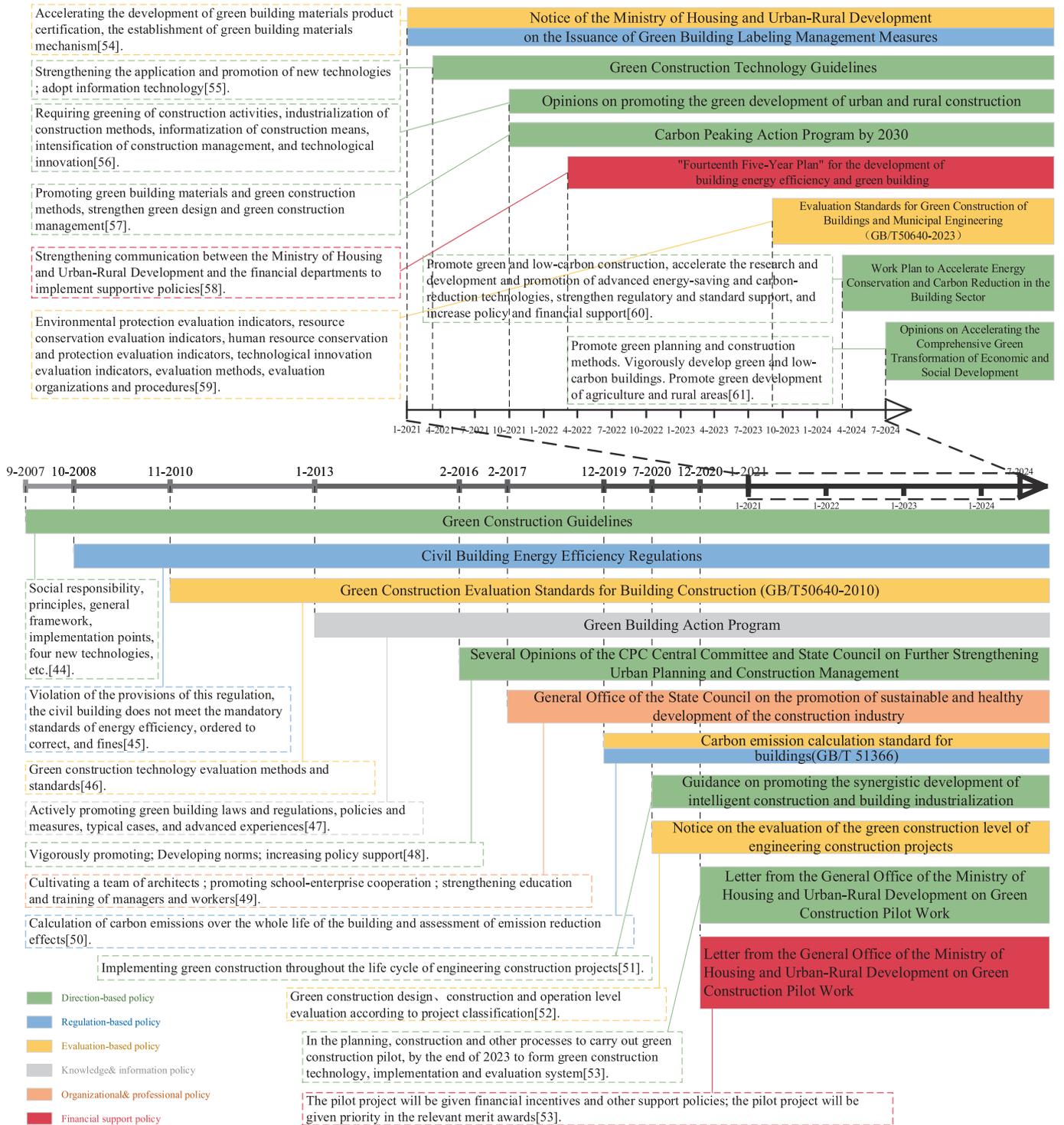


Fig. B-2. National policy-based initiatives related to green construction [44–61].

Data availability

Data will be made available on request.

References

- [1] United Nations Environment Programme. Global status report for buildings and construction: Towards a zero-emission, efficient and resilient buildings and construction sector, 2021.
- [2] IEA, (International Energy Agency), World Energy Investment. [EB/OL] 2021, <https://www.iea.org/reports/world-energy-investment-2021>.
- [3] IEA, (International Energy Agency), Tracking Clean Energy Progress 2021. [EB/OL] 2021, <https://www.iea.org/reports/tracking-buildings-2021>.
- [4] Wang J, Wei J. Characteristics and scenario simulation of carbon emission changes of building operation in Beijing under time series. J. Beijing University of Technology 2022;48:220–9 (in Chinese).
- [5] IEA, (International Energy Agency), An energy sector roadmap to carbon neutrality in China. [EB/OL] 2021, <https://www.iea.org/reports/an-energy-sector-roadmap-to-carbon-neutrality-in-china>.

- [6] Liu Z, et al. A review on macro-encapsulated phase change material for building envelope applications. *Build. Environ. Sustainability Indicators* 2018;144: 281–94.
- [7] Shi Q, Cai R, Huo T, You K, Cai W. A fairly and effectively analysis for the sharing of CO₂ emissions reduction responsibility in China's provincial building sectors. *Environ. Impact Assess. Rev.* 2023;99:106984.
- [8] Wang K-L, Pang S-Q, Zhang F-Q, Miao Z, Sun H-P. The impact assessment of smart city policy on urban green total-factor productivity: evidence from China. *Environ. Impact Assess. Rev.* 2022;94:106756.
- [9] Liu Z, et al. A state-of-the-art review on shallow geothermal ventilation systems with thermal performance enhancement system classifications, advanced technologies and applications. *Energy Built Environ.* 2021.
- [10] Liu Z, et al. Artificial intelligence powered large-scale renewable integrations in multi-energy systems for carbon neutrality transition: challenges and future perspectives. *Energy AI* 2022.
- [11] Huo T, et al. How does income level impact residential-building heating energy consumption? Micro-level evidence from household surveys. *Environ. Impact Assess. Rev.* 2021;91:106659.
- [12] Liu Y, Wang X-J, Zhou S, Chen H. Enhancing public building energy efficiency using the response surface method: an optimal design approach. *Environ. Impact Assess. Rev.* 2021;87:106548.
- [13] H. Kua, Integrated sustainability policies for China's cement industry—a case study approach, in *environmental change in Asia: challenges and prospects*, 2011.
- [14] Xie M, et al. Policies, applications, barriers and future trends of building information modeling technology for building sustainability and informatization in China. *Energy Rep.* 2022;8:7107–26.
- [15] Ropo M, Mustonen H, Knuutila M, Luoranen M, Kosonen A. Considering embodied CO₂ emissions and carbon compensation cost in life cycle cost optimization of carbon-neutral building energy systems. *Environ. Impact Assess. Rev.* 2023;101:107100.
- [16] Xu JK, Sun SM. The current situation, opportunities and challenges of green construction and sustainable development in Chinese airports. *Adv. Mat. Res.* 2014;860:1289–96.
- [17] Qing PA, et al. The evolution of the global bio-economy and suggestions for the development of bio-economy in China. *China J. Biol. Eng.* 2022;42:146–53 (in Chinese).
- [18] Pan W, Yu C, Du J. A dialectical system framework for green building assessment in high-density cities. *Environ. Impact Assess. Rev.* 2022;97:106860.
- [19] Queena K, Edwin H. Incentive instruments for government and private sector partnership to promote Building Energy Efficiency (BEE): a comparative study between Mainland China and some developed countries. *Women's Career Advancement Training Development in the 2008*;1384.
- [20] Zhang R, Tang Y, Zhang Y, Wang Z. Collaborative relationship discovery in green building technology innovation: evidence from patents in China's construction industry. *J. Clean. Prod.* 2023;391:136041.
- [21] He L, Sun Y, Xia Y, Zhong Z. Construction of a green development performance index of industrial enterprises: based on the empirical study of 458 listed industrial enterprises in China. *Ecol. Ind.* 2021;132.
- [22] Miao Z, Li L. in *ICCREM 2018: Sustainable Construction and Prefabrication*. VA: American Society of Civil Engineers Reston; 2018. p. 183–9.
- [23] Lina P. Green Building and green construction. *Intelligent Buildings* 2021;56–59 (in Chinese).
- [24] Li S, He B. On measures to promote green construction. *Management Engineering* 2012;103.
- [25] B. Hawang, J.S. Tan, Sustainable project management for green construction: challenges, impact and solutions, 2012.
- [26] Hasan M, Zhang R-J. Critical barriers and challenges in implementation of green construction in China. *Int. J. Curr. Eng. Technol.* 2016;6:435–45.
- [27] Shi Q, Zuo J, Huang R, Huang J, Pullen S. Identifying the critical factors for green construction—an empirical study in China. *Habitat Int.* 2013;40:1–8.
- [28] Yeung JF, Chan A, Chan D, Hong Y. Critical analysis of partnering research trend in construction journals. *J. Manag. Eng.* 2012;28:82–95.
- [29] Yi W, Chan AP. Critical review of labor productivity research in construction journals. *J. Manage. Eng. Habitat Int.* 2014;30:214–25.
- [30] Darko A, Chan APC. Critical analysis of green building research trend in construction journals. *Habitat Int.* 2016;57:53–63.
- [31] B. Pal, M. Ahmed, Measuring the publication productivity of NE-Indian universities using Scopus: a bibliometric analysis, 2014.
- [32] Cattan M, White M, Bond J, Learmouth A. Preventing social isolation and loneliness among older people: a systematic review of health promotion interventions. *Ageing Society* 2005;25:41–67.
- [33] Ibrahim KI, Costello SB, Wilkinson S. Key practice indicators of team integration in construction projects: a review. *Team Performance Manage.: Int. J.* 2013.
- [34] Akadirolu PO, Olomolaiye PO. Development of sustainable assessment criteria for building materials selection. *Eng. Constr. Archit. Manag.* 2012;19:666–87.
- [35] Mhurd. Ministry of Housing and Urban-Rural Development., Technical guidelines for Green Construction (Trial). *Construction supervision and inspection and cost* 14. 2021 (in Chinese).
- [36] You W, Xiao X. Study on the Development situation and prospects for green construction. *ICCREM 2015*;2015:272–81 (in Chinese).
- [37] Kibert CJ. *Sustainable construction: green building design and delivery*. John Wiley & Sons; 2016.
- [38] Ahn YH, Pearce AR, Wang Y, Wang G. Drivers and barriers of sustainable design and construction: the perception of green building experience. *Int. J. Sustain. Build. Technol. Urban Dev.* 2013;4:35–45.
- [39] Shen Y, Faure M. Green building in China. *Int. Environ. Agreeem.: Politics Law Econ.* 2020;21:183–99.
- [40] He Y, Kvan T, Liu M, Li B. How green building rating systems affect designing green. *Build. Environ.* 2018;133:19–31.
- [41] USGBC, Infographic: USGBC's Green Building Economic Impact Report.[EB/OL] 2015, <http://usgbc.org/articles/infographic-usgbc-s-green-building-economic-impact-report>.
- [42] Sang P, et al. Effects of project manager competency on green construction performance: the Chinese context. *Sustainability* 2018;10.
- [43] Zengwen B, Daming S, Borong L, Wusheng L, Jianrong Y. A review of green building development in China through practice and innovation. *HVAC* 2012;42: 1–8 (in Chinese).
- [44] Mhurdprc. Ministry of Housing and Urban-Rural Development of the People's Republic of China (in Chinese) Green Construction Guidelines[EB/OL] 2007. http://www.gov.cn/govweb/zwgk/2007-09/14/content_749545.htm.
- [45] GOSCPRC, (General Office of the State Council, PRC.), Civil Building Energy Efficiency Regulations.[EB/OL] 2008, http://www.gov.cn/flfg/2008-08/07/content_1067062.htm (in Chinese).
- [46] MHURDPRC. Ministry of Housing and Urban-Rural Development of the People's Republic of China. *Green Construction Evaluation Standards for Building Construction*. Beijing: China Construction Industry Press; 2014.
- [47] NDRCPRC, MHURDPRC, (National Development and Reform Commission, PRC, Ministry of Housing and Urban-Rural Development of the People's Republic of China.)Green Building Action Program.[EB/OL] 2013, http://www.gov.cn/zwgk/2013-01/06/content_2305793.htm (in Chinese).
- [48] XNA, (Xinhua News Agency.). Several Opinions of the CPC Central Committee and State Council on Further Strengthening Urban Planning and Construction Management.[EB/OL] 2016, http://www.xinhuanet.com/politics/2016-02/21/_1118109546.htm (in Chinese).
- [49] GOSCPRC, (General Office of the State Council of the People's Republic of China), General Office of the State Council on the promotion of sustainable and healthy development of the construction industry.[EB/OL] 2017, http://www.gov.cn/zhe ngce/content/2017-02/24/content_5170625.htm (in Chinese).
- [50] MHURDPRC, (Ministry of Housing and Urban-Rural Development of the People's Republic of China.), Carbon emission calculation standard for buildings. GB/T 51366-2019, (2019) (in Chinese).
- [51] MHURDPRC, NDRCPRC, MSTPRC, (Ministry of Housing and Urban-Rural Development, National Development and Reform Commission, Ministry of Science and Technology, PRC), Guidance on promoting the synergistic development of intelligent construction and building industrialization.[EB/OL] 2020, http://www.gov.cn/zhengce/zhengceku/2020-07/28/content_5530762.htm (in Chinese).
- [52] CACEM, (China Association of Construction Enterprise Management.), Notice on the evaluation of the green construction level of engineering construction projects.[EB/OL] 2020, <http://www.cacem.com.cn/n13/c39902/content.html> (in Chinese).
- [53] MHURDPRC, (Ministry of Housing and Urban-Rural Development of the People's Republic of China), Letter from the General Office of the Ministry of Housing and Urban-Rural Development on Green Construction Pilot Work.[EB/OL] 2020, https://www.mohurd.gov.cn/gongkai/fdzdgnr/tzgg/202101/20210105_248731.html (in Chinese).
- [54] MHURDPRC, (Ministry of Housing and Urban-Rural Development of the People's Republic of China.), Notice of the Ministry of Housing and Urban-Rural Development on the Issuance of Green Building Labeling Management Measures.[EB/OL] 2021, http://www.gov.cn/zhengce/zhengceku/2021-01/17/content_5580528.htm (in Chinese).
- [55] MHURDPRC, (Ministry of Housing and Urban-Rural Development of the People's Republic of China.), Green Construction Technology Guidelines.[EB/OL] 2021, <http://www.gov.cn/zhengce/zhengceku/2021-04/15/5599673/files/f09281359224c29ad9367e2ed23650d.pdf> (in Chinese).
- [56] GOCPC, GOSCPRC, (General Office of the Communist Party of China, General Office of the State Council of the People's Republic of China.), Opinions on promoting the green development of urban and rural construction.[EB/OL] 2021, http://www.gov.cn/xinwen/2021-10/21/content_5644083.htm (in Chinese).
- [57] GOSCPRC, (General Office of the State Council, PRC.), Carbon Peaking Action Program by 2030.[EB/OL] 2021, http://www.gov.cn/zhengce/content/2021-10/26/content_5644984.htm (in Chinese).
- [58] MHURDPRC, (Ministry of Housing and Urban-Rural Development of the People's Republic of China.), "Fourteenth Five-Year Plan" for the development of building energy efficiency and green building.[EB/OL] 2022, http://www.gov.cn/zhengce/zhengceku/2022-03/12/content_5678698.htm (in Chinese).
- [59] Announcement of the Ministry of Housing and Urban-Rural Development on the release of the national standard "Green Construction Evaluation Standard for Buildings and Municipal Engineering".[EB/OL] 2022, https://www.mohurd.gov.cn/gongkai/zc/wjk/art/2024/art_17339_776824.html (in Chinese).
- [60] Notice of the General Office of the State Council on forwarding the "Work Plan for Accelerating Energy Conservation and Carbon Reduction in the Building Sector" issued by the National Development and Reform Commission and the Ministry of Housing and Urban-Rural Development [EB/OL] 2024, https://www.gov.cn/zhengce/content/202403/content_6939606.htm (in Chinese).
- [61] Opinions of the CPC Central Committee and the State Council on Accelerating the Comprehensive Green Transformation of Economic and Social Development [EB/OL] 2024, https://www.gov.cn/zhengce/202408/content_6967663.htm (in Chinese).

- [62] W. Kai, Y. Jing, Green construction policy changes, complex levels and integrated paths under the “dual carbon” goal. *Journal of Shijiazhuang Tiedao University (Social Science Edition)*, (2022) (in Chinese).
- [63] Tan Y, Liu G, Zhang Y, Shuai C, Shen GQ. Green retrofit of aged residential buildings in Hong Kong: a preliminary study. *Build. Environ.* 2018;143:89–98.
- [64] Liu G, Li X, Tan Y, Zhang G. Building green retrofit in China: policies, barriers and recommendations. *Energy Policy* 2020;139.
- [65] Stieß I, Dunkelberg E. Objectives, barriers and occasions for energy efficient refurbishment by private homeowners. *J. Clean. Prod.* 2013;48:250–9.
- [66] Mickaityte A, Zavadskas EK, Kaklauskas A, Tupenaite L. The concept model of sustainable buildings refurbishment. *Int. J. Strateg. Prop. Manag.* 2008;12:53–68.
- [67] Alam M, et al. Government championed strategies to overcome the barriers to public building energy efficiency retrofit projects. *Sustainable Cities Society* 2019;44:56–69.
- [68] Shen L, He B, Jiao L, Song X, Zhang X. Research on the development of main policy instruments for improving building energy-efficiency. *J. Clean. Prod.* 2016; 112:1789–803.
- [69] Huang B, Mauerhofer V, Geng Y. Analysis of existing building energy saving policies in Japan and China. *J. Clean. Prod.* 2016;112:1510–8.
- [70] Darko A, Zhang C, Chan APC. Drivers for green building: a review of empirical studies. *Habitat Int.* 2017;60:34–49.
- [71] Ebrahimiagharehbaghi S, Qian QK, Meijer FM, Visscher HJ. Unravelling Dutch homeowners’ behaviour towards energy efficiency renovations: what drives and hinders their decision-making? *Energy Policy* 2019;129:546–61.
- [72] Jagarajan R, et al. Green retrofitting – a review of current status, implementations and challenges. *Renew. Sustain. Energy Rev.* 2017;67:1360–8.
- [73] Liang X, Peng Y, Shen GQ. A game theory based analysis of decision making for green retrofit under different occupancy types. *J. Cleaner Prod.* 2016;137: 1300–12.
- [74] A. Novikova et al., Information tools for energy demand reduction in existing residential buildings, CPI Report, Climate Policy Initiative, 2011.
- [75] K. Matschoss, E. Heiskanen, B. Atanasiu, L. Kranzl, in: Proceedings of the ECEEE, 2013, pp. 1485-1496.
- [76] Deng W, Yang T, Tang L, Tang Y-T. Barriers and policy recommendations for developing green buildings from local government perspective: a case study of Ningbo China. *Intell. Build. Int.* 2016;10:61–77.
- [77] Huang J, Fan J, Furbo S, Li Q. A policy study on the mandatory installation of solar water heating systems—Lessons from the experience in China. *Sol. Energy* 2020;206:614–27.
- [78] PGGP, (People’s Government of Guangdong Province.), Guangdong Green Building Action Implementation Plan.[EB/OL] 2013, https://www.gd.gov.cn/gkmlpt/content/0/142/post_142480.html#7 (in Chinese).
- [79] SCGPCC, (The Standing Committee of Guangdong Provincial People’s Congress.), Guangdong Green Building Regulations.[EB/OL] 2020, http://www.cnbayarea.org/g.cn/policy/policy%20release/policies/content/post_304255.html (in Chinese).
- [80] HCBSM, (Housing and Construction Bureau of Shenzhen Municipality.), Implementation Plan for the Action of Green Building Quality Development in Shenzhen (2021-2025) (Draft for Comments).[EB/OL] 2021, <http://zjj.sz.gov.cn/hdjlpt/yjzj/answer/16100> (in Chinese).
- [81] HURDDJP, (Housing and Urban-Rural Development Department of Jiangsu Province.), Notice on the promotion of the province’s green building development.[EB/OL] 2012, <https://www.jungreen.com/news/detail/8274653-ec95-44e4-b517-a7d10107e50c%20.html> (in Chinese).
- [82] PGC, (People’s Government of Changzhou Municipal.), Changzhou green construction pilot implementation program.[EB/OL] 2021, http://www.jiangsu.gov.cn/art/2021/7/30/art_34167_9960394.html (in Chinese).
- [83] PGJP, (People’s Government of Jiangsu Province), Jiangsu Provincial Government on accelerating the establishment of a sound green low-carbon cycle development of the implementation of the economic system views.[EB/OL] 2022, http://www.jiangsu.gov.cn/art/2022/1/25/art_46143_10331301.html (in Chinese).
- [84] PAMR, PDRC, PDIIT, (Provincial Administration of Market Regulation, Provincial Development and Reform Commission, Provincial Department of Industry and Information Technology.), On the in-depth promotion of green certification to promote green low-carbon cycle of development.[EB/OL] 2022, https://www.jiangsu.gov.cn/art/2022/3/25/art_46144_10389180.html (in Chinese).
- [85] HCIA, (Hubei Construction Industry Association), Hubei Province construction industry green construction and green construction technology application project management measures (for trial implementation).[EB/OL] 2020, <https://www.hbjzxh.org.cn/nd.jsp?id=329> (in Chinese).
- [86] HURDDHP, (Housing and Urban-Rural Development Department of Hubei Province.), Green Construction Technology Innovation Consortium Manual.[EB/OL] 2021, https://zjt.hubei.gov.cn/bmdt/dtyw/zjyw/202112/t20211220_3922806.shtml (in Chinese).
- [87] HURDDHP, (Housing and Urban-Rural Development Department of Hunan Province.), Hunan Province “Green Housing and Construction” Development Plan (2020-2025).[EB/OL] 2020, https://zjt.hunan.gov.cn/zjt/xxgk/xinxigongkaimulu/tzgg/tzgg2jzjnykj/202006/t20200602_12257729.html (in Chinese).
- [88] HURDDHP, (Housing and Urban-Rural Development Department of Hunan Province.), Hunan Province green building to create action to implement the program.[EB/OL] 2021, http://www.hunan.gov.cn/hnszf/szf/hnzb_18/2021/202106/szfbmwj_98721_88_1urmmqrurdbvpcutqhrmst/202104/t20210401_15493896.html (in Chinese).
- [89] HURDDHP, (Housing and Urban-Rural Development Department of Hunan Province.), Hunan Province green construction pilot implementation program.[EB/OL] 2021, http://zjt.hunan.gov.cn/zjt/xxgk/xinxigongkaimulu/tzgg/tzgg2jzjnykj/202105/t20210521_19338322.html (in Chinese).
- [90] PWHP, (People’s Website of Hunan Province.), Hunan Province, green building development regulations.[EB/OL] 2021, <http://www.hnrd.gov.cn/content/2021/07/30/9722629.html> (in Chinese).
- [91] MHURDPRC, (Ministry of Housing and Urban-Rural Development of the People’s Republic of China.), Technical Guidelines for Green Construction Evaluation of Construction Projects in Hunan Province (for trial implementation).[EB/OL] 2021, http://www.gov.cn/zhengce/zhengceku/2021-04/15/content_5599673.htm (in Chinese).
- [92] Craveiro F, Duarte JP, Bartolo H, Bartolo PJ. Additive manufacturing as an enabling technology for digital construction: a perspective on Construction 4.0. *Autom. Constr.* 2019;103:251–67.
- [93] SMD, (Sanxiang Metropolis Daily.), Hunan will select at least 10 projects as green construction pilot.[EB/OL] 2021, <https://sxdsb.voc.com.cn/article/202105/20210521182340199001.html> (in Chinese).
- [94] HURDDHP, (Housing and Urban-Rural Development Department of Hunan Province.), Notice on the establishment of Hunan Provincial Green Construction Expert Committee.[EB/OL] 2021, http://zjt.hunan.gov.cn/zjt/xxgk/xinxigongkaimulu/tzgg/tzgg2jzjnykj/202107/t20210719_19948003.html (in Chinese).
- [95] Yanan L, Jie H. Hunan: what are the results of the two-year green construction pilot project? *Hunan Daily* 2023 (in Chinese).
- [96] Changzhou will fully implement green construction from 2024 [EB/OL] 2023, https://www.jiangsu.gov.cn/art/2023/10/26/art_88959_11059757.html (in Chinese).
- [97] Notice of the Provincial Department of Housing and Urban-Rural Development on expanding the green construction pilot work in the province.[EB/OL] 2024, http://jsszfxcxjst.jiangsu.gov.cn/art/2024/4/28/art_8639_11230400.html (in Chinese).
- [98] Ning H. Foreign green construction development experience and cases. *Intelligent Buildings* 2021;37–42 (in Chinese).
- [99] U.K.Department for Environment Food & Rural Affairs. Clean Air Strategy 2019, 2019.
- [100] U.K.Environment Agency. Discharges to surfacewater and groundwater: environmental permits, 2024.
- [101] HM Revenue & Customs. Landfill Tax rates for 2023 to 2024, 2023.
- [102] U.K. Department for Energy Security and NetZero. Net Zero Strategy: Build Back Greener, 2021.
- [103] U.S. Department of State. The United States Officially Rejoins the Paris Agreement, 2021.
- [104] U.S. Congress., “Clean Competition Act,” 2022.
- [105] U.S. Environmental Protection Agency. National Recycling Strategy, 2021.
- [106] Singapore Building and Construction Authority. Sustainable Construction: A Guide on the Use of Recycled Materials, 2008.
- [107] Singapore Government. Singapore Green Plan 2030, 2021.
- [108] Singapore National Climate Change Secretariat. Singapore’s Long-Term Low-Emissions Development Strategy, 2020.
- [109] Singapore National Environment Agency. Carbon Pricing Act, 2019.
- [110] Zhichun Y. Low-carbon buildings in the UK: regulatory system and technical application. *J. Western Human Settlements Environ.* 2021;36:51–6.
- [111] U.S. Housing and Urban Development Department. Manufactured Home Construction and Safety Standards, 2021.
- [112] U.S. National Institute of Building Sciences. U.S. National BIM Program: implementation Plan, 2022.
- [113] Singapore Building and Construction Authority. Built Environment Industry Transformation Map(ITM).[EB/OL] 2023, <https://www1.bca.gov.sg/buildsg/built-environment-industry-transformation-map>.
- [114] Singapore Building and Construction Authority. BuildSG Transformation Fund.[EB/OL] 2024, <https://www1.bca.gov.sg/buildsg/buildsgtransformation-fund>.
- [115] Green Buildings Innovation Cluster (GBC) Programme.[EB/OL] 2023, <https://www1.bca.gov.sg/buildsg/buildsg-transform-ation-fund/green-buildings-innovation-cluster-gbc-programme>.
- [116] BRE Group. BREEAM technical standards, 2023.
- [117] U.S. Green Building Council. LEED rating system, 2024.
- [118] Singapore Building and Construction Authority Green Mark 2021, 2021.
- [119] Singapore Building and Construction Authority. Green Mark Incentive Schemes.[EB/OL] 2023, <https://www1.bca.gov.sg/buildsgsustainability/green-mark-inc-entive-schemes>.
- [120] Z. Dan, M. Kung, B. Whiteford, et al., Analysis of Sustainable Materials Used in Ecovillages: Review of Progress in BedZED and Masdar City, *J. Wuhan University of Technology (Materials Science Edition)* 27 (2012) 1004-1007.
- [121] Apple Headquarters YN. *World Architecture Review* 2021;36:48–52 (in Chinese).
- [122] Xiaodong Z. Marina Bay Sands Hotel, Singapore. *World Architecture* 2011;82–89 (in Chinese).
- [123] Singapore Building and Construction Authority. Singapore Green Building Masterplan 2021. (2022).
- [124] Zhicheng W, Grace J, Smith JK. Development trend of the prefabricated building industry in the United States (Part 1). *China Build. Metal Struct.* 2017;24–31 (in Chinese).
- [125] L. Yujie, L. Yuanheng, W. Na, et al., Foreign green construction development experience and inspiration, *Green Constr. Intell. Build.*, (2024) 13-19 (in Chinese).
- [126] Ying Liu J, Pheng Low S, He X. Green practices in the Chinese building industry. *J. Technol. Manage. China* 2012;7:50–63.
- [127] Wu Z, Jiang M, Cai Y, Wang H, Li S. What hinders the development of green building? An Investigation of China. *Int. J. Environ. Res. Public Health* 2019;16.

- [128] Zhang X, Shen L, Wu Y. Green strategy for gaining competitive advantage in housing development: a China study. *J. Clean. Prod.* 2011;19:157–67.
- [129] Geng Y, Doberstein B. Developing the circular economy in China: challenges and opportunities for achieving 'leapfrog development'. *Int. J. Sustainable Develop. World Ecol.* 2008;15:231–9.
- [130] Liu P-D. A novel method for hybrid multiple attribute decision making. *Knowl.-Based Syst.* 2009;22:388–91.
- [131] Hsu Y-L, Lee C-H, Kreng VB. The application of Fuzzy Delphi Method and Fuzzy AHP in lubricant regenerative technology selection. *Expert Syst. Appl.* 2010;37:419–25.
- [132] Kuo T-C, Wu H-H, Shieh J-I. Integration of environmental considerations in quality function deployment by using fuzzy logic. *Expert Syst. Appl.* 2009;36:7148–56.
- [133] Li R-J. Fuzzy method in group decision making. *Comput. Math. Appl.* 1999;38:91–101.
- [134] Zhang X, Platten A, Shen L. Green property development practice in China: costs and barriers. *Build. Environ.* 2011;46:2153–60.
- [135] Weck M, Klocke F, Schell H, Rüenauer E. Evaluating alternative production cycles using the extended fuzzy AHP method. *Eur. J. Oper. Res.* 1997;100:351–66.
- [136] Liang X, Yu T, Hong J, Shen GQ. Making incentive policies more effective: an agent-based model for energy-efficiency retrofit in China. *Energy Policy* 2019; 126:177–89.
- [137] Zheng D, Yu L, Wang L, Tao J. Integrating willingness analysis into investment prediction model for large scale building energy saving retrofit: using fuzzy multiple attribute decision making method with Monte Carlo simulation. *Sustain. Cities Soc.* 2019;44:291–309.
- [138] Bjerneboe MG, Svendsen S, Heller A. Initiatives for the energy renovation of single-family houses in Denmark evaluated on the basis of barriers and motivators. *Buildings* 2018;167:347–58.
- [139] Feng Q, Shi X, Zhang J. Influence of rent-seeking on safety supervision in Chinese construction: based on a simulation technology. *Technol. Forecasting Social Change* 2019;138:1–9.
- [140] Yau Y. Eco-labels and willingness-to-pay: a Hong Kong study. *Smart Sustainable Built Environ.* 2012.
- [141] Huo X, Ann T, Darko A, Wu Z. Critical factors in site planning and design of green buildings: a case of China. *J. Clean. Prod.* 2019;222:685–94.
- [142] Yin S, Li B, Xing Z. The governance mechanism of the building material industry (BMD) in transformation to green BMI: the perspective of green building. *Sci. Total Environ.* 2019;677:19–33.
- [143] Bangbade JA, Kamaruddeen AM, Nawi MNM, Yusoff RZ, Bin RA. Does government support matter? Influence of organizational culture on sustainable construction among Malaysian contractors. *Int. J. Constr. Manag.* 2018;18:93–107.
- [144] Love PE, Holt GD, Shen LY, Li H, Irani Z. Using systems dynamics to better understand change and rework in construction project management systems. *Int. J. Proj. Manag.* 2002;20:425–36.
- [145] Shi Q, Zuo J, Zillante G. Exploring the management of sustainable construction at the programme level: a Chinese case study. *Constr. Manage. Econom.* 2012;30:425–40.
- [146] Zhushan WB. The current situation of the implementation of green construction in China and the measures for its promotion. *J. Chongqing University Constr.* 2005; 27:97–100 (in Chinese).
- [147] Liu X, Hu W. Attention and sentiment of Chinese public toward green buildings based on Sina Weibo. *Sustain. Cities Soc.* 2019;44:550–8.
- [148] Wang W, Zhang S, Su Y, Deng X. Key factors to green building technologies adoption in developing countries: the perspective of Chinese designers. *Sustainability* 2018;10:4135.
- [149] Hwang BG, Tan JS. Green building project management: obstacles and solutions for sustainable development. *Sustain. Dev.* 2012;20:335–49.
- [150] Durdyev S, Zavadskas EK, Thurnell D, Banaitis A, Ihtiyar A. Sustainable construction industry in Cambodia: awareness, drivers and barriers. *Sustainability* 2018;10:392.
- [151] Hu H, Geertman S, Hooimeijer P. The willingness to pay for green apartments: the case of Nanjing. *China Urban Stud.* 2014;51:3459–78.
- [152] Gou Z, Lau S-S-Y, Prasad D. Market readiness and policy implications for green buildings: case study from Hong Kong. *J. Green Build.* 2013;8:162–73.
- [153] B. Baer, Sustainable retrofits in existing buildings analysis of stakeholder types, requirements, and perceptions in decision making, using the house of quality, 2012.
- [154] Darko A, Chan APC. Review of barriers to green building adoption. *Sustain. Dev.* 2017;25:167–79.
- [155] Osmani M, O'Reilly A. Feasibility of zero carbon homes in England by 2016: a house builder's perspective. *Build. Environ.* 2009;44:1917–24.
- [156] Li Y, Yang L, He B, Zhao D. Green building in China: needs great promotion. *Sustainable Cities Society* 2014;11:1–6.
- [157] Abidin N, Zainul, investigating the awareness and application of sustainable construction concept by Malaysian developers. *Habitat Int.* 2010;34:421–6.
- [158] E. Tagaza, J. Wilson, Green buildings: drivers and barriers e lessons learned from five Melbourne developments. Report Prepared for Building Commission by University of Melbourne Business Outlook Evaluation, 2004.
- [159] Eisenberg D, Done R, Ishida L. *Breaking down the barriers: challenges and solutions to code approval of green building.* AZ: Development Center for Appropriate Technology Tucson; 2002.
- [160] Bao L, Zhao J, Zhu N. Analysis and proposal of implementation effects of heat metering and energy efficiency retrofit of existing residential buildings in northern heating areas of China in "the 11th Five-Year Plan" period. *Energy Policy* 2012;45:521–8.
- [161] Hou J, Liu Y, Wu Y, Zhou N, Feng W. Comparative study of commercial building energy-efficiency retrofit policies in four pilot cities in China. *Energy Policy* 2016; 88:204–15.
- [162] Quirapas MAJR, Lin H, Abundo MLS, Brahim S, Santos D. Ocean renewable energy in Southeast Asia: a review. *Renew. Sustain. Energy Rev.* 2015;41:799–817.
- [163] Huang N, et al. Social network analysis of factors influencing green building development in China. *Int. J. Environ. Res. Public Health* 2018;15.
- [164] Masia T, Kajimo-Shakantu K, Opawole A. A case study on the implementation of green building construction in Gauteng province, South Africa. *Manage. Environ. Quality: Int. J.* 2020.
- [165] W. Wang, M. Ma, Evaluation System of Green Building and Its Application in Engineering Practice, 2019.
- [166] Al-Jebouri MF, Saleh MS, Raman SN, Rahmat RAABO, Shaaban AK. Toward a national sustainable building assessment system in Oman: assessment categories and their performance indicators. *Sustain. Cities Soc.* 2017;31:122–35.
- [167] Cohen C, Pearlmutter D, Schwartz M. Promoting green building in Israel: a game theory-based analysis. *Build. Environ.* 2019;163:106227.
- [168] Vierra S. Green building standards and certification systems. Washington, DC: National Institute of Building Sciences; 2016.
- [169] Li J, Shui B. A comprehensive analysis of building energy efficiency policies in China: status quo and development perspective. *J. Clean. Prod.* 2015;90:326–44.
- [170] Wang X, et al. Improving benefit-cost analysis to overcome financing difficulties in promoting energy-efficient renovation of existing residential buildings in China. *Appl. Energy* 2015;141:119–30.
- [171] Rainwater B, Martin C. *Local leaders in sustainability: green counties.* American Institute of Architects 2008.
- [172] Choi C. Removing market barriers to green development: principles and action projects to promote widespread adoption of green development practices. *J. Sustainable Real Estate* 2009;1:107–38.
- [173] Wang T, Foliente G, Song X, Xue J, Fang D. Implications and future direction of greenhouse gas emission mitigation policies in the building sector of China. *Renew. Sustain. Energy Rev.* 2014;31:520–30.
- [174] Shan M, Liu W-Q, Hwang B-G, Lye J-M. Critical success factors for small contractors to conduct green building construction projects in Singapore: identification and comparison with large contractors. *Environ. Sci. Pollut. Res.* 2020;27:8310–22.
- [175] Lam PT, Chan EH, Poon CS, Chau CK, Chun KP. Factors affecting the implementation of green specifications in construction. *J. Environ. Manage.* 2010; 91:654–61.
- [176] Gao C, Hou H, Zhang J, Zhang H, Gong W. Education for regional sustainable development: experiences from the education framework of HHCEPZ project. *J. Clean. Prod.* 2006;14:994–1002.
- [177] Lu L, Liu H, Bai X, Li T, Fu H. Case study on construction of green university and assessment indexes. *Environ. Sci. Manage.* 2007;32:182–5.
- [178] Barth M, Rieckmann M. Academic staff development as a catalyst for curriculum change towards education for sustainable development: an output perspective. *J. Clean. Prod.* 2012;26:28–36.
- [179] Boks C, Diehl JC. Integration of sustainability in regular courses: experiences in industrial design engineering. *J. Clean. Prod.* 2006;14:932–9.
- [180] Lozano R. Diffusion of sustainable development in universities' curricula: an empirical example from Cardiff University. *J. Clean. Prod.* 2010;18:637–44.
- [181] Jia J, Xu J, Fan Y. Public acceptance of household energy-saving measures in Beijing: Heterogeneous preferences and policy implications. *Energy Policy* 2018; 113:487–99.
- [182] Kong X, Lu S, Wu Y. A review of building energy efficiency in China during "Eleventh Five-Year Plan" period. *Energy Policy* 2012;41:624–35.
- [183] Olubunmi OA, Xia PB, Skitmore M. Green building incentives: a review. *Renew. Sustain. Energy Rev.* 2016;59:1611–21.
- [184] Fan K, Chan EH, Chau CK. Costs and benefits of implementing green building economic incentives: Case study of a gross floor area concession scheme in Hong Kong. *Sustainability* 2018;10:2814.
- [185] Yang G, Zhou Y. 2010 International Conference on Management and Service Science. IEEE; 2010. p. 1–5.
- [186] Mehta H, Porwal V. Green building construction for sustainable future. *Civil Environ. Res.* 2013;3:7–13.
- [187] Fu J, Geng Y. Public participation, regulatory compliance and green development in China based on provincial panel data. *J. Clean. Prod.* 2019;230:1344–53.
- [188] Xing J. Research on the stakeholder management model of modern enterprises. Northwest University; 2008 (in Chinese).