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Current Situation and Countermeasure Analysis of Low-Carbon Development in the Chinese Construction Industry

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Abstract: Currently, China has established a range of standards related to building energy efficiency, green practices, and low-carbon development. The construction industry has made significant progress in achieving green and low-carbon goals; however, numerous challenges remain. This paper examines the issues confronting the green and low-carbon development of the construction industry and proposes strategies to facilitate low-carbon growth in this sector within China. These strategies include enhancing research and development efforts to lower the additional costs associated with low-carbon buildings, strengthening the promotion and publicity of low-carbon buildings, improving energy conservation and carbon reduction in existing buildings, encouraging the growth of prefabricated buildings, providing guidance and regulation for low-carbon rural construction, refining market mechanisms to support the low-carbon development of the construction industry, and advocating for low-carbon lifestyles.

Keywords: Construction industry; Low-carbon development; Countermeasures

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1. The green and low-carbon development of China's construction industry has achieved remarkable results

The government has consistently emphasized the importance of promoting energy efficiency, sustainability, and low-carbon practices within the construction sector. Since the 1980s, China has enacted key legislation such as the Energy Conservation Law, the Renewable Energy Law, and the Regulations on Energy Conservation in Civil Buildings, establishing a solid legal framework for advancing building energy savings [1]. To address the challenges posed by climate change, China has actively encouraged energy conservation and emission reduction initiatives in the construction industry alongside fostering the development of zero-energy and zero-carbon buildings. A range of policies and standards related to energy-efficient, green, and low-carbon buildings have also been introduced. In 2015, the country released the Design Standards for Energy Efficiency of Public Buildings, followed by the

Evaluation Standards for Green Buildings, Technical Standards for Near-Zero Energy Buildings, and Carbon Emission Calculation Standards for Buildings in 2019. More recently, in 2021, China unveiled the General Code for Building Energy Efficiency and Renewable Energy Utilization, which comprehensively addresses various aspects of engineering construction and different types of buildings, steering the construction industry toward a more sustainable, low-carbon future.

In 2020, China made a commitment to "double carbon" goals, marking the construction industry's transition into an era of "carbon neutrality." In March 2022, the Ministry of Housing and Urban-Rural Development released the "14th Five-Year Plan for Building Energy Efficiency and Green Building Development." This plan stipulates that by 2025, all new buildings in urban areas should meet green building standards. Additionally, it emphasizes the need for steady improvements in building energy efficiency, gradual optimization of the energy structure, and effective control of the increasing trend in building-related energy consumption and carbon emissions. Ultimately, this aims to establish a development model characterized by green, low-carbon, and circular construction practices.

On June 30, 2022, the Ministry of Housing and Urban-Rural Development and the National Development and Reform Commission released the Implementation Plan for Achieving Carbon Peak in Urban and Rural Construction. This plan established a key objective for reducing carbon emissions from buildings: By 2030, carbon emissions in urban and rural construction are expected to reach their peak. By the year 2060, the aim is to fully transform the construction model of urban and rural areas into one that is comprehensively green and low-carbon [2].

By the close of 2022, the mandatory standards for building energy efficiency have been fully implemented in new urban buildings across the country. The cumulative construction area of energy-saving buildings in China has exceeded 30.3 billion square meters, and energy-saving buildings account for over 64% of the urban civil construction area.

2. Problems faced by the green and low-carbon development of China's construction industry

2.1. Both construction enterprises and consumers lack enthusiasm for low-carbon buildings

Despite the government issuing a range of standards to encourage the growth of low-carbon buildings, while some companies have taken steps, the majority of construction companies and consumers in the market remain unenthusiastic about this concept. From an environmental protection and social responsibility standpoint, construction enterprises should opt for low-carbon materials and utilize low-carbon technologies and methods in their projects. However, due to the underdeveloped nature of current low-carbon technologies, additional costs are often incurred. Although low-carbon technology might yield advantages in the long term, these benefits typically do not accrue to construction companies. If such increased costs are passed on to consumers, it could dampen their purchasing intentions. Moreover, most consumers' understanding of low-carbon buildings is limited to environmental concerns, believing that buying such properties does not offer them personal benefits, which further diminishes their motivation to purchase low-carbon buildings.

2.2. China's existing buildings are large in quantity and wide in scope, and the problem of energy consumption is prominent

Due to the rapid development of urbanization, the scale of construction areas in China continues to expand, which has led to a significant increase in the stock of older buildings. These early constructions often have lower building standards, shorter design lifespans and face challenges such as insufficient structural strength, high operational

energy consumption, limited functional use, and safety concerns. Additionally, issues like aging pipelines and excessive energy consumption are particularly prominent. Demolishing and reconstructing buildings that are still usable would result in a substantial waste of energy resources. Therefore, enhancing the existing building structures, improving their safety and functionality, and reducing energy consumption through retrofitting technologies will play a crucial role in China's pursuit of low-carbon building development.

Despite China's significant accomplishments in advancing energy conservation and carbon reduction for existing buildings, numerous challenges remain. For instance, building retrofit technologies for energy efficiency are still under development, the costs associated with such retrofits are relatively high, and the initiatives are largely government-driven. Additionally, there is a need to innovate the methods used for energy-saving transformations. These issues impede the effective implementation of energy-saving retrofits for existing buildings.

2.3. The country vigorously promotes prefabricated buildings, but the market has mixed opinions on them

In contrast to the conventional method of on-site casting, prefabricated buildings have increasingly gained attention due to their benefits in energy conservation, material saving, emission reduction, and pollution reduction. In recent years, the government has implemented various policies aimed at promoting the growth of prefabricated construction. In October 2021, the State Council released the "Action Plan for Achieving Carbon Peak by 2030," which emphasized accelerating the adoption of prefabricated buildings and advancing building industrialization. Subsequently, in 2022, the 14th Five-Year Plan for Construction Industry Development outlined a strategy to significantly expand the use of prefabricated buildings, with a target of having over 30% of new constructions utilize this technology by 2025. Furthermore, in May 2022, the Ministry of Finance announced the "Financial Support for Carbon Peak and Carbon Neutrality Initiatives", reiterating the importance of expediting the application of prefabricated buildings and eco-friendly materials [3].

Nevertheless, shifting from conventional construction to prefabricated construction demands substantial financial and technical resources. It is projected that the additional cost for prefabricated construction projects amounts to 260 yuan per square meter, which significantly impedes its advancement due to higher expenses compared to traditional methods [3]. Moreover, the current capacity and production rate of prefabricated component factories often fail to satisfy construction site requirements. This leads to longer construction periods for prefabricated buildings when contrasted with traditional techniques, further obstructing the growth of prefabricated buildings.

2.4. China's construction industry has achieved remarkable results in energy conservation and carbon reduction, but rural areas are rarely included in the scope of control

In 2022, China's carbon emissions from building operations were categorized by building type as follows: 940 million tons of CO_2 for public buildings, 890 million tons of CO_2 for urban residential buildings, and 480 million tons of CO_2 for rural residential buildings. The carbon emissions from rural residential buildings account for roughly 20% of the nation's total building operational emissions. Currently, China has achieved significant progress in promoting low-carbon development in buildings; however, there is an imbalance in the advancement of energy-saving and carbon-reduction efforts between urban and rural areas. Urban building regulations have been well-developed, but a large number of rural buildings remain outside the scope of energy-saving and carbon-reduction controls. Additionally, policies, standards, technologies, and systems tailored to the unique characteristics

of rural buildings require further refinement. Presently, rural buildings often lack proper planning and design, with many constructed based on individual preferences. Aesthetic considerations tend to take precedence over energy efficiency and carbon reduction, and there is a shortage of relevant guidance documents. This results in a high degree of randomness in rural construction practices. Consequently, rural residential buildings present substantial potential for energy savings and carbon reductions, which requires attention.

2.5. The government is still the main promoter of the low-carbon development of the construction industry, and the marketization mechanism has not yet formed

Currently, the construction industry's transition toward low-carbon practices primarily depends on administrative measures and financial backing, with the government continuing to play a dominant role in driving this transformation. However, the variety of financial tools employed to support the green and low-carbon advancement of the construction sector remains limited, and financial institutions require enhanced innovation capabilities [4]. Regarding the national carbon market, there is no defined roadmap for incorporating the construction industry into this framework [5]. Despite the significant overall emissions from the construction sector, individual buildings emit relatively small amounts of carbon, and single projects offer limited potential for emission reductions, making it challenging to include the industry in the national carbon market. Furthermore, market-driven mechanisms, such as building carbon emission tracking, energy performance contracting, and integrated energy efficiency services, need further development.

3. Countermeasure analysis for promoting the low-carbon development of China's construction industry

3.1. Strengthen technology research and development efforts, reduce the incremental cost of low-carbon buildings

The implementation of low-carbon technology in construction often results in higher costs and adds complexity to the building process. The capacity for innovation plays a crucial role in determining the advancement of green and low-carbon technologies, while the technological proficiency influences the additional expenses associated with green and low-carbon buildings [6]. Only low-carbon technologies that are simple, applicable, and profitable can be favored by construction companies. Consequently, enhancing the innovation and exploration of low-carbon technology is essential. By promoting collaborative research among universities, research institutes, and construction enterprises, the incremental cost of low-carbon buildings can be continuously reduced, and the difficulty of construction can be lowered. At the same time, the government needs to increase the promotion of suitable technologies, promote the research and application of new technologies, materials, equipment, and construction methods to continuously develop low-carbon technologies.

3.2. Strengthen the publicity and promotion of low-carbon buildings, improve market acceptance

If the public has a high recognition of low-carbon buildings, they will likely be more willing to purchase them. This increased demand can serve as a significant driving force for construction companies to develop more environmentally friendly buildings. Consequently, local governments at all levels should actively promote educational campaigns about low-carbon buildings, spreading knowledge of their benefits and how they contribute to environmental improvement and resource conservation. Such efforts aim to strengthen public environmental

consciousness and a sense of social responsibility. On the other hand, purchasing and usage costs remain key factors influencing buying decisions. Given that low-carbon buildings offer advantages over traditional ones in terms of energy efficiency, they often lead to operational cost reductions during use. It is essential to find straightforward and clear methods to communicate these benefits to consumers, alleviating concerns that low-carbon buildings might involve higher expenses. By doing so, we can enhance public trust and acceptance of low-carbon buildings.

3.3. Focus on existing buildings and promote energy saving and carbon reduction transformation work

First, it is essential to enhance the research and development of energy-saving transformation technologies. This includes actively advancing the technologies required for precise repairs and renovation, such as building structural stability diagnosis and evaluation technology, building structural reinforcement technology, structural insulation performance improvement technology, replacement and use technology of energy-efficiency equipment and renewable energy, etc. Second, the government should promote the income and emission reduction benefits associated with retrofitting existing buildings for energy efficiency. By conducting comparative analyses of operational data and costs of buildings before and after renovation, the advantages and outcomes of energy-saving renovations can be demonstrated to the public, thereby increasing their confidence in investing in such projects.

Currently, the government continues to play a significant role in advancing the energy-saving retrofit of existing buildings, which demands substantial funding in the initial phase. It is essential to focus on innovating investment and financing approaches, channel capital toward energy-saving renovation initiatives, and leverage market-oriented mechanisms to create a sustainable framework for the energy-saving retrofit of existing structures.

3.4. Solve the bottleneck problem, help the development of prefabricated buildings

First, it is essential to enhance funding for scientific research, focusing on improving the environmental friendliness and usability of materials and components by investigating fundamental theoretical issues associated with prefabricated buildings. To address the high construction costs of prefabricated buildings, research efforts should be directed toward developing standardized design approaches and systematic integrated design strategies. This will help refine the manufacturing processes of relevant components and parts in prefabricated buildings, as well as identify methods to cut down on construction expenses [7].

Since China has only recently begun to actively promote the development of prefabricated buildings, there is a shortage of technical and management talents, as well as skilled industrial workers, in the design, manufacturing, construction, and other related fields of prefabricated buildings. Therefore, it is necessary to accelerate the training of specialized personnel and promote the integration of information technology with the development of prefabricated buildings.

Specialized research must be conducted on the issue of low construction efficiency in prefabricated buildings to identify the underlying causes and explore solutions across the entire industry chain. Furthermore, government bodies should oversee the planning and guidance of pilot demonstration projects for prefabricated buildings and encourage the advancement and adoption of relevant technologies by promoting these pilot initiatives. Simultaneously, there should be enhanced policy support for prefabricated buildings in areas such as finance and awards to facilitate their overall development.

3.5. Expand the concept of green and low-carbon to rural areas and strengthen low-carbon guidance and control of rural buildings

Currently, the quality of architectural design in rural areas tends to be relatively low, showing a significant disparity when compared to urban buildings. To address this, the government could offer exemplary rural architectural design templates for housing reference while also guiding aspects such as the appropriate height of rural buildings, window-to-wall ratio configurations, and residential layouts. Additionally, rural construction teams often lack professionalism and are not adequately guided by green and low-carbon concepts, leading to extensive construction practices that result in the wastage of material resources. It is crucial to enhance the qualification management of these rural construction teams and provide them with regular training. On one hand, promoting green construction practices is essential, while on the other hand, there should be a focus on utilizing local green building materials to minimize the embodied carbon emissions of rural construction materials. Based on the specific conditions in rural areas, it is necessary to investigate cost-effective, straightforward, and easily implementable green and low-carbon construction technologies and methods [8].

The inferior quality of building materials, including doors and windows, stands as a significant factor contributing to high carbon emissions in rural building operations. When constructing houses, rural residents frequently prioritize initial input costs, opting for low-quality materials like doors and windows that have limited lifespans. This results in two major issues: firstly, poor air tightness during usage, which boosts energy consumption; secondly, the brief lifespan of these materials necessitating frequent replacements, further escalating carbon emissions from buildings. It is crucial to encourage rural residents to evaluate both construction and usage costs holistically when building houses. Additionally, enhancing the oversight and regulation of rural building materials can effectively prevent substandard products and equipment from entering the market.

3.6. Build a green financial system and improve the market-based promotion mechanism for the low-carbon development of the construction industry

The advancement of green finance represents a crucial strategy for achieving low-carbon development within the construction sector. By offering a variety of green financial products and services, it becomes possible to address the diverse requirements of market participants while simultaneously enhancing the supply structure of the green financial market. Efforts should focus on innovating different forms of green bond instruments and expanding financial tools such as green development funds, green insurance, and carbon finance to support sustainable growth. Additionally, it is essential to reinforce regulatory cooperation regarding green finance activities and products, refine associated regulatory frameworks, standardize trading procedures, and increase market transparency. Furthermore, proactive exploration into incorporating the construction industry into the national carbon market through systematic design and methodological approaches can facilitate its low-carbon transformation and development via market-driven mechanisms.

3.7. Advocate low-carbon life and reduce carbon emissions during building operation

Numerous studies have demonstrated that, when considering the entire life cycle, carbon emissions during the building operation phase constitute the primary source of overall building-related carbon emissions. Extensive measured comparative analyses indicate that variations in lifestyle and usage patterns are the most crucial factors contributing to differences in the operational energy consumption of buildings [9]. Decreasing the carbon emission intensity of building operations is an essential task for China in achieving its “carbon peak and carbon neutrality” goals [10].

It is essential to promote a simple, moderate, green, and low-carbon lifestyle and consumption mindset among the population. This can be achieved by conducting extensive campaigns to raise awareness about energy conservation and carbon reduction while encouraging the adoption of green and low-carbon living principles. Through community events and other methods, residents should be educated on reducing carbon emissions, enabling the public to recognize the direct connection between their lifestyle choices and carbon reduction efforts. The ideals of energy efficiency and low-carbon practices should be integrated into societal norms, emphasizing that saving energy and reducing carbon emissions are shared responsibilities of the entire society. Encourage individuals to prioritize the selection of energy-saving and environmentally friendly appliances in their daily lives, fostering good habits in energy usage. By taking action at the grassroots level, people can effectively decrease carbon emissions during the operational phase of buildings.

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