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POLICY-DRIVEN SUSTAINABLE PROPERTY DEVELOPMENT: STRATEGIC PATHWAYS AND SYSTEMIC CHALLENGES IN CHINA'S DUAL CARBON TRANSITION

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Abstract: Under the synergistic drive of China's "Dual Carbon" strategy and macro-control policies such as "housing is for living, not speculation" and the "three red lines" regulation, the real estate industry faces dual challenges and opportunities in green transformation and sustainable development. As a pillar of the national economy, real estate enterprises urgently need to resolve contradictions and bottlenecks in low-carbon transition through management innovation and technological upgrading. This study systematically examines the intrinsic connection between carbon neutrality goals and the real estate sector, revealing practical challenges including carbon footprint measurement deficiencies, green technology application gaps, intensified financing constraints, and policy adaptation dilemmas. The research proposes a multidimensional implementation framework: Strengthening corporate awareness of green transition while establishing a carbon-neutral business ecosystem; enhancing carbon accounting capabilities and energy efficiency through technological innovation, complemented by carbon offset and compensation mechanisms; deepening ESG practices to reduce debt financing costs, with empirical evidence demonstrating that improved ESG ratings significantly optimize credit asset structures under green finance policies. Furthermore, the study outlines actionable pathways such as low-carbon building standards and green supply chain management, aligning with macro-control objectives. These findings provide theoretical support for real estate enterprises to balance regulatory compliance with market opportunities, formulate carbon reduction strategies, and accelerate the realization of China's "Dual Carbon" vision through industry-wide sustainable transformation.
Keywords: Green real estate development; Dual carbon goals; Policy instruments; Low-carbon transition; Interest coordination

1 INTRODUCTION

1.1 Background of the Study

Against the backdrop of the global response to climate change, China has actively assumed the responsibility of a great power and put forward a "dual-carbon" strategic goal, i.e., striving to achieve carbon peaking by 2030 and carbon neutrality by 2060. The proposal of this strategic goal is not only an important contribution of China to global climate governance, but also has far-reaching impacts on the development of various domestic industries. As one of the pillar industries of China's national economy, the real estate industry occupies an important position in economic and social development. However, the traditional real estate development model is often accompanied by high energy consumption and high emissions. From the production and transportation of building materials, to energy consumption during building construction, to daily energy consumption during the use phase of buildings, the real estate industry generates a large amount of carbon emissions throughout its life cycle[1]. According to relevant statistics, carbon emissions from the real estate industry account for a large proportion of China's total social carbon emissions. At the same time, in order to promote the stable and healthy development of the real estate market, the Chinese government has issued a series of macro-control policies, in which the positioning of "housing without speculation" clarifies the residential property of real estate, curbing speculative behavior in the real estate market and guiding the market back to rationality. The "three red lines" policy has imposed strict restrictions on the financing of real estate enterprises, aiming to reduce the leverage of enterprises and prevent financial risks. The implementation of these policies has caused real estate enterprises to face unprecedented financial pressure and market competition challenges. Driven by the synergy of the "dual-carbon" strategy and macro-control policies, the real estate industry is facing the dual challenges and opportunities of green transformation and sustainable development. On the one hand, enterprises need to cope with the strict requirements of the policy to solve the various contradictions and bottlenecks encountered in the process of low-carbon transformation; on the other hand, the green transformation has also brought new market opportunities and development space for enterprises. For example, as consumers' awareness of environmental protection increases, there is a growing demand for green, low-carbon and healthy real estate products[2].

1.2 Current Status of Related Research at Home and Abroad

Overseas, many developed countries have carried out a great deal of research and practice in the low-carbon development of the real estate sector. Some studies focus on the development and application of green building

technologies, such as highly efficient insulation materials and solar photovoltaic systems, to improve the energy efficiency of buildings. There are also studies focusing on the sustainable development strategies of real estate companies, exploring how to achieve low-carbon transformation through management innovation and technological upgrading. For example, some European countries have promoted the active adoption of green building technologies by real estate companies through the formulation of strict building energy consumption standards and carbon emission regulations.

Domestically, with the proposal of the "double carbon" goal, the research on the low-carbon development of the real estate industry is also increasing[3]. Domestic studies mainly focus on the path and strategy of low-carbon transformation of the real estate industry, such as how to promote low-carbon development of real estate enterprises through policy guidance, technological innovation and market mechanisms. In addition, some studies also focus on the accounting methods and standards for carbon emissions in the real estate industry, in order to accurately assess the carbon emissions of real estate projects. However, the current domestic studies still have certain deficiencies in the accuracy of carbon footprint measurement, the practical application effect of green technologies, and the adaptability of policies, which require further in-depth research.

1.3 Impact of the "Dual-Carbon" Strategy on the Real Estate Sector

Opportunities for green transformation: The real estate industry is one of China's pillar industries and a major contributor to energy consumption and carbon emissions. The implementation of the "dual-carbon" strategy will prompt real estate companies to accelerate the pace of green transformation, promote the development of green buildings, assembly buildings and other new building forms, and improve the energy efficiency and environmental performance of buildings. This will not only help reduce carbon emissions in the real estate industry, but also meet consumer demand for green, healthy and comfortable living environments and enhance the market competitiveness of enterprises. Therefore, an in-depth study of the intrinsic links between the carbon peak and carbon neutral targets and the real estate industry, revealing the practical challenges faced by real estate companies in the process of low-carbon transformation and proposing corresponding strategic paths and solutions, is essential for real estate companies to balance compliance regulation and market opportunities, formulate effective carbon emission reduction strategies, and promote the sustainable transformation of the industry as a whole in order to realize the vision of " Double Carbon" in China. It is of great theoretical and practical significance for real estate enterprises to balance compliance regulation and market opportunities, formulate effective carbon reduction strategies, and promote the sustainable transformation of the whole industry to realize China's "dual carbon" vision.

2 TECHNOLOGIES RELATED TO SUSTAINABLE DEVELOPMENT IN THE REAL ESTATE INDUSTRY

2.1 Techniques for Accurate Carbon Footprint Measurement

Measurement method innovation: At present, China's real estate industry has obvious deficiencies in carbon footprint measurement, and lacks a unified and accurate measurement method. Therefore, it is necessary to develop a carbon footprint measurement model that is suitable for the whole life cycle of real estate projects in China by combining international advanced experience with China's national conditions. For example, drawing on the Life Cycle Assessment (LCA) methodology, the carbon emissions of building materials production, transportation, construction, operation and demolition should be comprehensively considered at each stage. Introducing big data and Internet of Things (IoT) technology to collect real-time data on building energy consumption and building materials usage to improve the accuracy and timeliness of carbon footprint measurement. By installing smart sensors in buildings, real-time monitoring of energy consumption, water usage, etc., and uploading the data to the cloud for analysis[4].

Formulation of measurement standards: Promote the establishment of unified carbon footprint measurement standards for the industry, and clarify the calculation methods and boundaries of carbon emissions at various stages. Relevant government departments, industry associations and research institutes should work together to formulate a real estate carbon footprint measurement standard system that meets China's "dual-carbon" goal. Strengthen the qualification and supervision of measurement organizations to ensure the reliability and comparability of measurement results. Establish an access mechanism and a monitoring and evaluation system for measurement organizations, and regularly evaluate their measurement capabilities and results.

2.2 Green Technology Application and Innovation

1. Promotion of energy-saving technologies: vigorously promote energy-efficient building designs and technologies, such as solar photovoltaic integration, ground-source heat pumps, and high-efficiency thermal insulation materials. In new buildings, it is mandatory to adopt a certain percentage of energy-saving technologies and products to improve the energy utilization efficiency of buildings. Carry out energy-saving renovation of existing buildings to reduce building energy consumption by replacing windows and doors, adding insulation and optimizing HVAC systems. Subsidy policies and incentives for energy-saving renovation of existing buildings have been formulated to encourage owners and enterprises to actively participate in the renovation.

2. Research and development and application of green building materials: Increase investment in research and

development of green building materials and encourage enterprises to develop new environmentally friendly and low-carbon building materials. For example, research and development of recyclable building materials, bio-based materials, etc., to reduce carbon emissions during the production of traditional building materials. Establish a certification system for green building materials and strengthen the supervision of the green building materials market to ensure the quality and performance of green building materials. Through the certification mark and market access system, guide real estate enterprises to prioritize the use of green building materials.
3. Intelligent management technology application: the introduction of building intelligent management system realizes intelligent monitoring and management of building energy, equipment and environment. Through the intelligent control system, energy consumption is automatically adjusted according to the actual use of the building, and energy utilization efficiency is improved. Using big data and artificial intelligence technology, it analyzes and predicts building operation data to provide decision support for optimal operation and maintenance of the building. For example, by analyzing historical energy consumption data, it predicts future energy demand and adjusts energy supply strategies in advance.

2.3. Carbon Offset and Compensation Technologies

1. Carbon sink project development: Encourage real estate companies to participate in the development of carbon sink projects, such as tree planting and wetland protection. By investing in the construction of carbon sink projects, they can offset the carbon emissions of their own projects. Enterprises can cooperate with forestry departments and environmental protection organizations to jointly develop carbon sink projects and obtain corresponding carbon emission reduction credits. Establish a carbon sink trading market to provide real estate enterprises with a carbon sink trading platform. Through the market mechanism, promote the rational allocation and effective utilization of carbon sink resources.
2. Alternative technologies for renewable energy: Promote the use of renewable energy in real estate projects as an alternative to traditional energy sources, such as solar energy, wind energy and water energy[5]. In building design, reserve space and interfaces for the installation of renewable energy equipment, and encourage owners and enterprises to install and use renewable energy equipment. Developing distributed energy systems to realize the local production and utilization of energy. For example, distributed solar power stations are being built in residential communities to provide clean energy for residents.

2.4 Technology Integration and Collaborative Innovation

1. Multi-technology integrated application: Integrate carbon footprint measurement, green technology application, carbon offset and compensation and other technologies to form an integrated low-carbon technology solution. Through system integration, realize the synergistic effect of various technologies and improve the low-carbon level of real estate projects. Establish a technology integration platform to promote information sharing and exchange between different technologies. For example, through the establishment of a digitization platform, real-time sharing of information such as carbon footprint measurement data and the effect of green technology application can be realized.
2. Collaborative innovation among industry, academia, research and application: Strengthening cooperation among real estate enterprises, scientific research institutions and universities to carry out research and development and innovation of low-carbon technologies. Through the cooperation between industry, academia and research institutes, scientific research results will be transformed into practical applications, and the technological progress of the real estate industry will be promoted. Establish an industry-university-research-utilization cooperation mechanism to jointly undertake scientific research projects and carry out technological innovation activities. For example, enterprises provide practical application scenarios and financial support, while research institutions and universities provide technical research and development and talent training services. Figure 1 shows the relevant technologies for the sustainable development of the real estate industry.

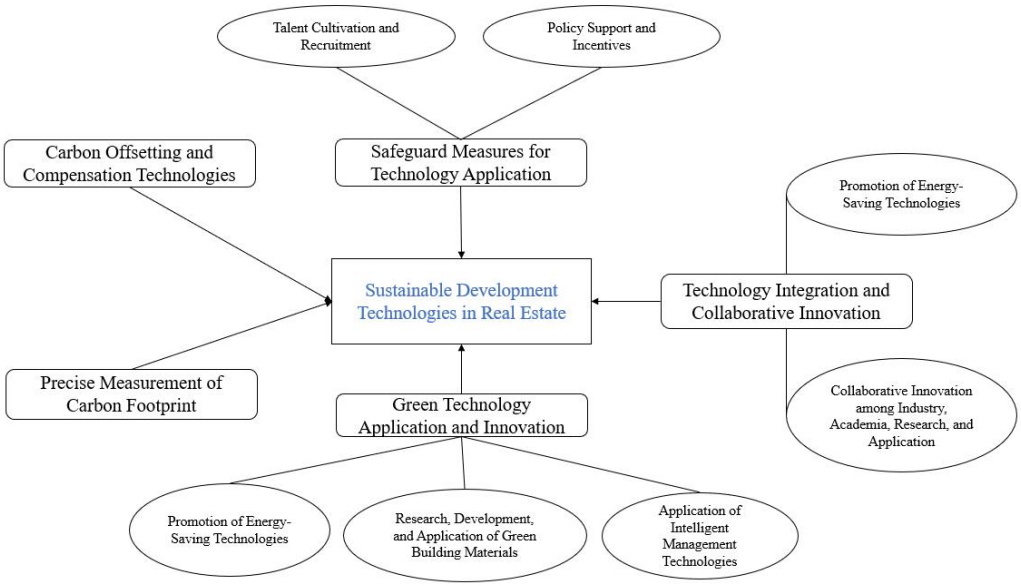

Figure 1 The Technologies Related to Sustainable Development in the Real Estate Industry

2.5. Safeguards for the Application of Technology

1. Cultivation and introduction of talents: Strengthen the cultivation of professionals related to low-carbon technology, open relevant majors and courses in colleges and vocational schools, and cultivate professionals adapted to the needs of low-carbon transformation of the real estate industry. Introduce advanced low-carbon technology talents from home and abroad to improve the technological innovation ability of enterprises. Attract high-end talents to join real estate enterprises through preferential policies and favorable working environment.
2. Policy support and incentives: The government has issued relevant policies to support real estate projects that adopt low-carbon technologies with tax incentives and financial subsidies. For example, enterprises constructing green buildings are given a certain percentage of tax breaks, and financial subsidies are given to projects adopting renewable energy. Establish a technological innovation incentive mechanism to recognize and reward enterprises and individuals who have made outstanding achievements in the research, development and application of low-carbon technologies.

3 FIT BETWEEN THE "NO SPECULATION ON HOUSING" POLICY AND GREEN DEVELOPMENT

As an important macro-control tool, the policy of "housing without speculation" is closely linked to the green development of the real estate industry. This section will explore the interface between the policy of "housing without speculation" and green development, in order to reveal the potential opportunities and feasible paths for the real estate industry to realize green transformation in the context of this policy.

3.1 The Role of the "Housing Without Speculation" Policy in Regulating the Real Estate Market

The policy of "housing without speculation" is aimed at returning to the residential property of housing, curbing speculation in the real estate market and promoting the stable and healthy development of the real estate market. The implementation of this policy has rationalized the relationship between supply and demand in the real estate market and reduced market bubbles and instability[6]. From the demand side, the policy has guided consumers to focus more on the actual use value and living quality of housing rather than pure investment returns. This has prompted real estate companies to focus more on improving the quality and performance of housing, creating market demand for green development. From the supply side, the policy restricts the blind expansion and over-development of real estate enterprises, prompting them to pay more attention to the long-term benefits and sustainability of their projects, which provides an intrinsic motivation for green development.

3.2 Market Opportunities for Green Development under the Policy of "Housing without Speculation"

The implementation of the policy of "housing without speculation" has made the real estate market more focused on quality and service, which has brought broad market opportunities for green development. On the one hand, consumers' awareness of and demand for green housing is increasing, and they are willing to pay higher prices for green housing. Real estate companies can meet consumer demand and improve market competitiveness by developing green projects. On the other hand, the government's support for green development has been increasing, and a series of preferential policies and incentives have been introduced, such as financial subsidies, tax reductions and exemptions, and volume rate incentives. Real estate companies can take advantage of these policies to reduce the cost of green development and

improve the economic efficiency of their projects.

3.3 Synergies between the Policy of "Housing without Speculation" and Green Development in Terms of Policy Objectives

The goal of the "housing without speculation" policy is to promote the stable and healthy development of the real estate market and to safeguard the housing needs of residents, while the goal of green development is to achieve sustainable development of the economy, society and the environment. Both have synergies in terms of policy objectives, and both are committed to promoting high-quality development of the real estate industry. These points of convergence provide favorable conditions for the green transformation and sustainable development of the real estate industry. By combining the policy of "housing without speculation" with green development, we can achieve a balance between supply and demand in the real estate market, a reasonable allocation of resources and effective protection of the environment, and contribute to the realization of China's "dual-carbon" goal. This will contribute to the realization of China's "dual-carbon" goal.

4 FORCING MECHANISM OF THE "THREE RED LINES" POLICY FOR LOW-CARBON TRANSFORMATION OF ENTERPRISES

4.1 Overview of the "Three Red Lines" Policy

The "Three Red Lines" policy is an important initiative of China's macro-control of real estate, including the gearing ratio after excluding advance receipts shall not be greater than 70%, the net debt ratio shall not be greater than 100%, and the cash-to-short-debt ratio shall not be less than one times. The introduction of this policy aims to regulate the financing behavior of real estate enterprises, control the financial risks of the real estate industry, and guide enterprises to rationally arrange funds to avoid over-indebtedness and blind expansion. The implementation of this policy has had a far-reaching impact on the financial situation and business strategies of real estate enterprises, prompting them to re-examine their own development model and strategic direction.

4.2 Financial Pressure on Enterprises under the "Three Red Lines" Policy

Under the constraints of the "three red lines" policy, real estate enterprises are facing tremendous financial pressure. As many enterprises have long relied on a high-debt, high-turnover development model, after the implementation of the policy, the gearing ratio, net debt ratio and other indicators may exceed the requirements of the red line, resulting in restricted financing channels. Banks and other financial institutions have become more stringent in approving loans for enterprises stepping on the line, and the scale of new financing for enterprises has been restricted, and the cost of financing has increased accordingly. At the same time, in order to meet the policy requirements, enterprises need to accelerate sales returns and reduce the level of indebtedness, which further aggravates the enterprise's financial constraints. This financial pressure makes enterprises have to seek new development paths to alleviate financial difficulties. Table 1 shows the sustainable real estate development paths, key challenges and countermeasures under the policy-driven.

Table 1 Policy-Driven Sustainable Property Development in China's Dual Carbon Transition

Policy Category	Strategic Pathways	Systemic Challenges	Key Implementation Measures	Case/Data Support
Dual Carbon Targets	1. low carbon building standardization and certification 2. Green technology innovation and application (e.g. BIPV, smart energy system)	1. Lack of standards for carbon footprint measurement 2. High cost and difficulty in promoting green technologies	1. Establishment of industry carbon accounting systems 2. Government subsidies and tax incentives	By 2022, China's certified green building area will exceed 6.6 billion square meters (Source: Ministry of Housing and Construction)
"Housing for Living" Regulations	1. Green renovation of stock housing 2. Sustainable design for sheltered housing	1. Inadequate funding for energy efficiency retrofits in older buildings 2. Significant regional differences in policy implementation	1. Issuance of green bonds to support urban renewal 2. Development of local guidelines on low-carbon buildings	Pilot "zero-carbon community" projects in Beijing and Shanghai (e.g., Beijing Urban Vice Center)
Green Finance Policies	1. ESG ratings linked to financing costs 2. Carbon market participation	1. Weak ESG disclosure capacity of SMEs 2. Low liquidity of carbon assets	1. Development of an ESG disclosure framework for the real estate sector 2. Innovation in carbon financial instruments (e.g. carbon mortgages)	Green bond issuance scale of real estate enterprises increased by 23% year-on-year in 2023 (Source: Wind Data)

Supply Chain Sustainability	1. Proportion of mandatory procurement of green building materials 2. Supplier carbon footprint tracking	1. Insufficient supply of low-carbon alternatives for building materials 2. Low supply chain transparency	1. Establishment of green building materials database 2. Blockchain technology enables supply chain traceability	Vanke's "Green Chain Action" covers 80% of its suppliers (Source: Enterprise Annual Report)
Regional Coordination	1. Pilot trans-regional carbon emissions trading 2. Eco-compensation mechanisms	1. Uneven regional development makes policy synergies difficult 2. Local protectionism hinders resource flows	1. Interconnection of carbon emissions trading in the Yangtze River Delta/Great Bay Region 2. Targeted support from central financial transfers	Guangdong Province will account for 28% of the country's carbon emission quota turnover in 2022 (Source: Guangdong Carbon Exchange)

Looking ahead, with the in-depth promotion of the "dual-carbon" strategy, the forcing effect of the "three red lines" policy on the low-carbon transformation of enterprises will become more obvious. Enterprises need to further strengthen technological innovation, increase capital investment, and improve the management system of low-carbon transformation to adapt to policy and market requirements. The government should also continue to improve the relevant policies to provide more support and guidance for the low-carbon transformation of enterprises, and jointly promote the sustainable development of the real estate industry to achieve China's "dual-carbon" goal[7].

5 SYSTEMIC CHALLENGES OF LOW CARBON TRANSITION IN CHINA'S REAL ESTATE SECTOR

5.1 Numerous Shortcomings in Carbon Footprint Measurement

In the context of the real estate industry's transition to low-carbon and sustainable development, accurate carbon footprint measurement is of critical importance. First of all, carbon footprint measurement is the basis for enterprises to formulate scientific and reasonable emission reduction targets and strategies. Real estate development involves a number of complex processes, such as land acquisition, building construction, and operation and management, each of which generates different levels of carbon emissions. By accurately measuring the carbon footprint, companies can clearly understand the carbon emissions of each link, so that they can take targeted emission reduction measures, avoid blind actions, and improve the efficiency of emission reduction. However, there are many shortcomings in the current carbon footprint measurement 1. Uniform measurement standards: At present, China's real estate industry lacks uniform and authoritative carbon footprint measurement standards. Different measurement organizations may adopt different methods and parameters, resulting in a lack of comparability and accuracy of measurement results. For example, when calculating carbon emissions during building construction, some organizations only consider carbon emissions during the production and transportation of building materials, while ignoring the energy consumption of construction machinery and carbon emissions during waste disposal. Such inconsistency in standards makes it difficult for enterprises to accurately assess their carbon emission levels, and also brings difficulties to governmental supervision.2. Difficulty in obtaining data: Carbon footprint measurement requires the support of a large amount of accurate data, including data on the production of construction materials, energy consumption, and data on waste disposal, etc. In practice, however, it is difficult to obtain data for the measurement of carbon footprint. However, in practice, there are many difficulties in data acquisition. On the one hand, some enterprises have not established a perfect data collection and recording system due to the lack of data management awareness, resulting in missing or inaccurate data. On the other hand, some data involve commercial secrets of enterprises, which enterprises are reluctant to disclose to the public, further increasing the difficulty of data acquisition. For example, suppliers of construction materials may be reluctant to provide detailed carbon emission data during their production process, making it difficult for real estate companies to calculate the carbon footprint of construction materials.3. Inadequate measurement methods: Existing carbon footprint measurement methods have certain limitations and are unable to comprehensively and accurately reflect the carbon emissions of real estate projects. For example, the current measurement methods mainly focus on the calculation of direct carbon emissions and give insufficient consideration to indirect carbon emissions. Indirect carbon emissions from real estate projects include carbon emissions from upstream and downstream enterprises in the supply chain, carbon emissions during consumer use, etc. These indirect carbon emissions often account for a large proportion of the total carbon emissions of the project. In addition, the existing measurement methods are not mature enough to calculate the carbon emissions of some emerging technologies and materials, leading to bias in the measurement results.

Suggestions for solving the carbon footprint measurement problem are as follows: 1. Establish a unified measurement standard: The government should take the lead in organizing relevant departments and industry associations to formulate a unified and authoritative carbon footprint measurement standard for the real estate industry. The standards should specify the measurement scope, methods and parameters to ensure the comparability and accuracy of the measurement results. At the same time, publicity and training on the measurement standards should be strengthened to enhance the understanding and application capabilities of enterprises and measurement organizations.2. Strengthen data management: Real estate enterprises should set up a comprehensive data collection and recording system to strengthen data management on the production of building materials, energy consumption, and waste disposal. The government

can encourage enterprises to adopt advanced information technology means to realize real-time data collection, transmission and analysis through policy guidance and financial support[8]. In addition, the construction of a data-sharing platform should be strengthened to promote data sharing among enterprises and between enterprises and the government, and to improve the efficiency of data utilization.3. Improvement of Measurement Methods: Scientific research institutes and enterprises should strengthen the research and innovation of carbon footprint measurement methods, and continually improve the measurement methods. Consideration should be given to including indirect carbon emissions in the scope of measurement and adopting more advanced technologies and models to improve the accuracy and comprehensiveness of measurement. At the same time, research on the carbon emissions of emerging technologies and materials should be strengthened and reasonable carbon emission calculation methods should be developed for them.

5.2 Bottlenecks in the Application of Green Technologies

5.2.1 Barriers to the promotion of green building technology

In the green transformation process of China's real estate industry, the promotion of green building technology faces many difficulties. First, the green building technology standard system is not perfect. At present, although China has introduced a series of standards and norms related to green building, there are some problems in the practical application of these standards. For example, there are differences in the standards of different regions, which makes it difficult for real estate enterprises to apply green building technology uniformly when developing projects across regions. Moreover, the updating speed of some of the standards cannot keep up with the pace of technological development and cannot provide effective guidance and specifications for the latest green building technologies.

Secondly, the cost of green building technology is higher. Compared with traditional building technologies, green building technologies require higher inputs in terms of materials, equipment and construction techniques. Energy-efficient glass, for example, is usually 30% - 50% more expensive than ordinary glass. For real estate companies, the adoption of green building technology will significantly increase the construction cost of the project, which to a certain extent reduces the motivation of companies to apply green technology. In addition, the research and development and application of green building technologies require professional talents and technical teams, which also increases the labor costs of enterprises. In addition, the lack of market awareness and acceptance of green building is also an important issue. Most consumers do not have a deep enough understanding of the concepts and advantages of green building, and they are more concerned about traditional factors such as the price, location and house type of the house, and lack sufficient attention to the energy-saving and environmentally friendly features of green building. This makes real estate companies face certain difficulties in selling green building projects, further inhibiting the promotion of green building technology.

5.3 Intelligent Technology Integration Challenges

With the continuous development of science and technology, the application of intelligent technology in the field of real estate is getting more and more attention. However, the integration of intelligent technology faces many challenges in practical application. On the one hand, the compatibility of intelligentized systems is poor. Real estate projects involve a number of intelligent subsystems, such as security systems, energy management systems, smart home systems, and so on. These subsystems are often provided by different suppliers, and there are differences in communication protocols and data formats between them, making it difficult to achieve effective integration and cooperative work between the various systems. For example, the data collected by the security system cannot be timely and accurately transmitted to the energy management system, which affects the operational efficiency of the entire intelligent system. On the other hand, the maintenance and management of intelligent technology is difficult. Intelligent systems contain a large number of devices and software, which require professional technicians for maintenance and management. However, at present, China's real estate industry lacks composite talents who know both real estate and intelligent technology, which leads to the failure of the intelligent system in the operation process can not be repaired in time. Moreover, the intelligent technology is updated quickly, real estate enterprises need to continuously invest in system upgrades and updates, which also increases the operating costs of enterprises.

In addition, the security of intelligent technology is an issue that cannot be ignored. With the increase of intelligentized equipment and systems in real estate projects, the risk of data leakage and cyberattacks also increases. If the security measures of the intelligentized system are not in place, it may lead to problems such as the leakage of owners' personal information and the malicious control of equipment, which will bring great inconvenience and security risks to owners' lives.

5.4 Limitations of Renewable Energy Utilization

The application of renewable energy in real estate projects is one of the important ways to realize low-carbon transformation, but at present, there are certain limitations in the use of renewable energy in China's real estate industry. First, the stability of renewable energy is poor. Solar, wind and other renewable energy generation is greatly affected by natural conditions, for example, solar power generation can only be carried out during the day when there is sunlight, and wind power generation also requires sufficient wind conditions. This makes it difficult for renewable energy sources to meet the continuous power demand of real estate projects in practical application, and it needs to be

complemented with traditional energy sources. Second, the installation and maintenance costs of renewable energy equipment are high. The initial investment in renewable energy equipment such as solar photovoltaic panels and wind turbines is large, and their installation and maintenance require specialized technicians and equipment. For some small real estate companies, it is difficult to afford such high costs. In addition, renewable energy equipment has a relatively short service life and requires regular replacement and maintenance, which also increases the operating costs of the enterprise[9]. In addition, the grid connection problem of renewable energy is also an important issue. At present, China's power grid system is mainly designed for traditional energy sources, renewable energy power generation into the grid needs to meet certain technical standards and requirements. Due to the large intermittency and volatility of renewable energy power generation, it brings certain challenges to the stable operation of the grid. As a result, grid companies are more cautious about accessing renewable energy power generation, which to a certain extent limits the application of renewable energy in real estate projects.

5.5 The Policy Adaptation Dilemma

China's "dual carbon" transition and real estate macro-control policies, such as "housing without speculation" and the "three red lines", are intertwined and constantly updated, forming a complex system of policies. These policies are intertwined and constantly updated, forming a complex policy system. Real estate companies are faced with the challenge of how to accurately understand the intent of these policies and how to effectively integrate them into their daily operations and strategic planning. Different policies have different objectives and focuses. For example, the "dual carbon" policy emphasizes low-carbon development and green transformation, while the "three red lines" focuses more on financial health and debt risk control. Enterprises need to find a balance between the two to ensure that they meet low-carbon requirements without violating financial regulations. However, due to the subjectivity of policy interpretation and the limitations of enterprises' own capacity, many enterprises have deviated from the implementation process. Some enterprises may focus too much on low-carbon targets and neglect financial risks, resulting in a tight financial chain; others may be too conservative and make slow progress in low-carbon transformation, missing out on market opportunities. In addition, frequent policy adjustments increase the difficulty for enterprises to adapt. The government continuously optimizes policies based on market dynamics and national strategic goals, which requires companies to have the ability to react and adjust quickly. However, real estate projects are characterized by long construction cycles and large-scale investments. Once an enterprise has planned a project in accordance with the original policy, changes in the policy may result in the feasibility and economic benefits of the project being affected, and the enterprise will have to reevaluate and adjust the project plan, which undoubtedly increases the enterprise's operating costs and risks.

There are also differences in the level of development and resource endowment of the real estate market in different regions. In some economically developed regions, the market demand for green real estate is higher, enterprises are motivated to carry out low-carbon transformation, and the role of policy promotion is relatively obvious. In some economically underdeveloped regions, consumer awareness and acceptance of green building is low, market demand is insufficient, and the enthusiasm of enterprises to carry out low-carbon transformation is not high. At this time, if the government imposes uniform policy standards, it may lead to increased costs for enterprises and inhibit market vitality. Therefore, how to formulate more flexible and targeted policies to adapt to the actual situation of different enterprises and regions is an important issue that current policy makers need to address.

6 CONSTRUCTION OF A MULTIDIMENSIONAL IMPLEMENTATION FRAMEWORK

6.1 Enhancing Corporate Green Transition Awareness and Building Carbon Neutral Business Ecosystems

6.1.1 Importance of enhancing awareness of green transformation in enterprises

Under the synergistic promotion of the "dual-carbon" strategy and macro-control policies such as "housing without speculation" and "three red lines", real estate enterprises, as pillars of the national economy, have a great significance in enhancing their awareness of green transformation. Enhancement of real estate enterprises as the pillar of the national economy, its green transformation awareness is of great significance. On the one hand, from the perspective of the enterprise's own development, green transformation is the key to deal with the dual challenges and opportunities facing the industry. As consumers' awareness of environmental protection continues to improve, the market demand for green and sustainable real estate projects is increasing. If enterprises can enhance the awareness of green transformation in a timely manner, and develop real estate products that meet environmental standards and consumer demand, it will help to enhance the market competitiveness of enterprises and expand market share. On the other hand, from the social level, the real estate industry is one of the important areas of carbon emissions. Real estate enterprises to enhance the awareness of green transformation, and actively participate in low-carbon development, will help promote the green change of the industry as a whole, and contribute to the realization of the national "dual-carbon" goal. At the same time, this is also in line with the national macro-control guidance, which is conducive to the enterprises and the policy environment, to avoid the business risks brought about by policy adjustments.

6.1.2 Ways to Enhance Enterprises' Awareness of Green Transformation

Strengthening policy publicity and training: The Government and industry associations should strengthen the publicity

of the "dual-carbon" policy and the relevant requirements for green development, and organize real estate enterprises to participate in policy interpretation and training activities. Through these activities, enterprise managers can gain a deeper understanding of the policy background, objectives and specific requirements, and clarify the responsibilities and obligations of enterprises in green transformation. For example, policy seminars can be organized on a regular basis, inviting relevant policymakers and experts to give explanations and answer questions, helping enterprises to accurately grasp the direction of the policy.

Setting up industry benchmarks and role models: The industry should actively set up benchmark enterprises and successful cases of green transformation, and show the effectiveness and experience of green transformation to other enterprises through media publicity and industry exchanges. The demonstration effect of these benchmark enterprises can stimulate the enthusiasm and initiative of other enterprises, prompting them to learn from advanced green development concepts and practice methods. For example, a "green real estate enterprise" award can be selected to recognize and publicize enterprises with outstanding performance in green transformation.

Promote the construction of internal culture: real estate enterprises should actively create a cultural atmosphere of green development internally, and integrate the concept of green transformation into the values and development strategies of the enterprise. By carrying out internal training, publicity activities, etc., to improve the knowledge and understanding of all employees on green transformation, so that green development has become the conscious action of all employees of the enterprise. For example, a green development publicity column can be set up within the enterprise to regularly release knowledge and information related to green development.

6.2 Technological Innovation to Enhance Carbon Accounting Capacity and Energy Efficiency

In the process of low-carbon transformation of the real estate industry, accurate carbon accounting is crucial. However, there are currently many deficiencies in carbon accounting in China's real estate sector, such as inconsistent carbon footprint measurement methods and difficulties in data collection. Technological innovation provides an effective way to solve these problems. Advanced Internet of Things (IoT) technology can be applied to all aspects of real estate projects to realize real-time and accurate monitoring of energy consumption and carbon emission data. By installing various types of sensors in buildings, it is possible to collect data on a wide range of aspects, including power consumption, water usage, and the operation of air conditioning systems. These data can be integrated and analyzed through the IoT platform to clearly present the carbon footprint of a real estate project. For example, in a large commercial complex, the use of IoT sensors can be used to monitor the energy usage of each store in real time and accurately calculate the carbon emissions of different areas[10].

Big data analysis technology also plays an important role in carbon accounting. By deeply mining and analyzing a large amount of carbon emission data, more scientific and accurate carbon accounting models can be established. These models can take into account the characteristics of different regions and types of real estate projects and improve the accuracy of carbon accounting. At the same time, big data analysis can also predict the carbon emission trends of real estate projects at different stages, providing a basis for enterprises to formulate carbon reduction strategies.

Improving energy efficiency is key to achieving low-carbon development in the real estate sector. Technological innovation has great potential in this regard.

6.3 Alignment of Carbon Offsets with Compensation Mechanisms

In addition to enhancing carbon accounting capacity and energy efficiency through technological innovation, carbon offsetting and compensation mechanisms are important additions to the real estate industry's efforts to achieve low-carbon development. Carbon offsetting refers to enterprises offsetting their own carbon emissions by purchasing carbon emission reductions. Real estate enterprises can invest in some renewable energy projects, forest carbon sink projects, etc., in order to obtain the corresponding carbon emission reductions. For example, enterprises can participate in tree planting projects to absorb carbon dioxide through photosynthesis of trees, thus offsetting their own carbon emissions in the process of real estate development and operation. Carbon offsetting mechanism refers to the fact that enterprises reduce carbon emissions by adopting some measures and use the reduced carbon emissions to compensate for other unavoidable carbon emissions. For example, real estate enterprises can adopt more environmentally friendly building materials and construction techniques in the project development process to reduce carbon emissions during the construction process. At the same time, companies can use these reduced carbon emissions to compensate for unavoidable carbon emissions during project operations. Technology innovation, carbon offset and compensation mechanisms work together to form a complete low-carbon development system, helping real estate companies to better achieve carbon emission reduction targets and enhance the sustainable development of enterprises. Against the background of China's "dual-carbon" goal, real estate companies should actively embrace technological innovation, make full use of carbon offset and compensation mechanisms, and accelerate the pace of green transformation and sustainable development.

6.4 Deepening ESG Practices to Reduce Debt Financing Costs

6.4.1 Conceptualization of ESG practices

ESG stands for Environment, Social and Governance, which constitute an important system of indicators for measuring corporate sustainability. In the context of the real estate industry, ESG practices have rich and specific connotations.

From the environmental dimension, the ESG practices of real estate companies are mainly reflected in the protection of the environment and the sustainable use of resources. In the process of project development, companies need to consider how to reduce excessive consumption of natural resources such as land and water. For example, they can reduce energy consumption by adopting green building design concepts, optimizing the layout and orientation of buildings to improve natural lighting and ventilation, and reducing the use of artificial lighting and air-conditioning systems. Meanwhile, in the selection of building materials, priority should be given to environmentally friendly and renewable materials to reduce the generation of construction waste and pollution of the environment. During the operation phase of the project, an effective waste management and treatment mechanism should be established to collect and treat construction waste and domestic waste in a categorized manner, so as to improve the recycling rate of resources.

Under the current "dual-carbon" strategy and related macro-control policies, real estate enterprises should firstly strengthen their knowledge of ESG concepts in order to deepen their ESG practices. The management should fully realize that ESG is not only the embodiment of social responsibility, but also the key to achieving sustainable development and responding to market changes and policy requirements. By organizing internal training and seminars, all employees should understand the meaning and importance of ESG concepts and integrate ESG awareness into the corporate culture. At the same time, ESG strategy should be deeply integrated with the overall development strategy of the enterprise. ESG objectives and specific measures should be clearly defined in the long-term plan and annual plan of the enterprise, so as to ensure that ESG practices are closely integrated with the business operations and investment decisions of the enterprise. For example, ESG factors such as environmental impact assessment and social responsibility considerations should be included in the planning stage before project development, so as to promote the sustainable development of the project from the source.

6.4.2 Theoretical linkages between ESG practices and Debt financing of real estate firms

In today's economic environment, ESG (Environmental, Social and Governance) concepts have gradually become an important measure of corporate sustainability. For real estate companies, ESG practices are particularly critical as their operations involve a large number of issues such as resource consumption, community impact and internal management. From a theoretical perspective, good ESG practices can convey to the market a company's sustainability and social responsibility. Financial institutions will take ESG factors into consideration when assessing the credit risk of real estate companies. When a company has a high ESG performance, it means that it is able to effectively control carbon emissions and reduce resource wastage in environmental management, actively participate in community building and safeguard the rights and interests of employees in social responsibility, and have a sound internal control and decision-making mechanism in corporate governance. These positive factors will make financial institutions perceive the enterprise as having lower operational and default risks, and thus be more willing to provide debt financing to it, and may offer more favorable financing terms, such as lower interest rates and longer repayment periods.

6.4.3 Status of ESG practices of Chinese real estate enterprises

Currently, Chinese real estate companies have made some progress in ESG practices, but there are still many deficiencies. Some large real estate companies have begun to pay attention to ESG management and publish ESG reports to disclose their environmental, social and governance performance. For example, some enterprises are actively promoting the development of green buildings, adopting environmentally friendly materials and energy-saving technologies, and reducing carbon emissions throughout the life cycle of buildings. In terms of social responsibility, enterprises have also increased their investment in community building and public welfare. However, on the whole, a considerable number of real estate enterprises still do not have a deep enough understanding of ESG practices and lack a systematic ESG management system. Some companies only use ESG as a superficial means of publicity, but do not really integrate it into their strategies and daily operations. On the environmental front, some enterprises still have high energy consumption and high pollution development modes; on the social front, labor disputes and project quality problems occur from time to time; and on the governance front, problems such as imperfect internal control and non-transparent information disclosure still exist.

6.4.4 Strategies to deepen ESG practices to reduce debt financing costs

Based on the above analysis, real estate enterprises should adopt the following strategies to deepen ESG practices and reduce debt financing costs. First, they should strengthen ESG strategic planning, integrate ESG concepts into their overall development strategies, and formulate clear ESG goals and action plans. Secondly, they should strengthen ESG information disclosure, improve the quality and transparency of information disclosure, and convey to the market the image of enterprises actively fulfilling their social responsibilities and focusing on sustainable development. Furthermore, they should invest more in green building technology research and development, community building, and corporate governance to continuously improve their ESG performance. In addition, enterprises should actively communicate and cooperate with financial institutions to understand the requirements and directions of green financial policies, and strive to obtain more green financial support. By deepening ESG practices, real estate enterprises can not only reduce debt financing costs and optimize the credit asset structure, but also enhance their brand image and market competitiveness and achieve sustainable development, thus better meeting the requirements of China's "dual-carbon" strategy and macro-control policies, and contributing to promoting the green transformation and sustainable development of the entire real estate industry. It also contributes to the green transformation and sustainable development of the entire real estate industry.

Through the implementation of the above strategies, real estate companies can deepen ESG practices, reduce debt financing costs, optimize credit asset structure, and make positive contributions to the realization of China's

"dual-carbon" goal while achieving their own sustainable development.

7 CASE STUDIES

7.1 Criteria and Methodology for Case Selection

When studying the sustainable development of Chinese real estate companies in the context of the "dual-carbon" transition, it is important to select typical cases that are representative and useful. In order to ensure that the selected cases fully reflect the current situation, challenges and development path of the industry under the policy-driven environment, we have developed the following detailed criteria and methodology for case selection. In terms of enterprise size, it covers large, medium and small real estate enterprises. Large enterprises usually have stronger financial strength, wider business layout and stronger social influence, and are often able to play a leading role in green transformation, such as Vanke and BGL. They have the ability to invest a lot of resources in green technology R&D and application, and establish a perfect green supply chain system. Medium-sized enterprises have a certain degree of competitiveness and flexibility in the market, and their transformation experience is a direct reference value for many enterprises of the same size. Small-sized enterprises, on the other hand, face more resource constraints and market pressures, and their exploration and attempts in the transformation process can provide ideas for other small-sized enterprises in the industry to cope with the challenges. The geographical distribution of enterprises is also an important consideration. China is a vast country, and there are significant differences in the level of economic development, policy environment and market demand in different regions. The selection of cases from developed eastern coastal regions, central regions and western regions can fully reflect the characteristics and differences of real estate enterprises in different regions in the "dual-carbon" transition. For example, the eastern coastal region is economically developed, with strong policy support and high market acceptance of green real estate, and the enterprises started earlier and developed relatively maturely in green transformation; while the western region may face unique challenges in resource utilization and ecological protection, and the transformation practices of its enterprises are also characterized by regional characteristics. The extent of enterprises' green development practices is one of the key criteria. We will select enterprises with remarkable achievements in green building certification, energy saving and emission reduction measures, green supply chain management, etc., as well as enterprises in the exploratory stage of green transformation and facing various challenges. The former can demonstrate successful experiences and models, while the latter can reveal difficulties and problems in the transition process. Through the study of enterprises with different degrees of practice, it can provide targeted reference for real estate enterprises at different stages of development. In terms of case selection methods, extensive literature research is first conducted to collect industry reports, news reports, academic studies and other information to initially screen the list of enterprises that meet some of the criteria[11]. Then, through the official website of the enterprises, annual reports, sustainability reports and other channels, we further understand the detailed information of the enterprises, including their green development strategies, project practices, technology applications and other aspects. At the same time, combined with the opinions and suggestions of industry experts, the preliminary screened enterprises are evaluated and screened to determine the final typical cases.

7.2 Introduction of Typical Case Companies

As one of the leading companies in China's real estate industry, Vanke has always been a leader in green development. The company put forward its green building development strategy many years ago and is committed to creating high-quality green residential and commercial projects. Up to now, Vanke has developed a large number of green building certified projects in several cities across China, such as Shanghai Vanke Jade Riverside and Shenzhen Vanke Cloud City. These projects have adopted a series of advanced green technologies, such as solar photovoltaic power generation system, ground source heat pump technology, rainwater collection system, etc., which effectively reduce energy consumption and carbon emissions. In terms of green supply chain management, Vanke actively cooperates with suppliers to promote green procurement and sustainable production. The company has formulated strict supplier evaluation criteria and prioritized suppliers with environmental awareness and green production capacity. Vanke also strengthens environmental management at construction sites and promotes green construction techniques to reduce environmental pollution and resource waste during the construction process. In response to the "double carbon" target, Vanke further clarified its carbon reduction target and action plan. The company plans to gradually increase the proportion of green building projects in the next few years, increase the use of renewable energy, and strengthen carbon emission accounting and management. Through these initiatives, Vanke has not only set an example of green development for the industry, but also made positive contributions to the realization of the "double carbon" goal.

Lanson Green Properties focuses on the development of green technology homes with the product concept of "Green, Healthy and Comfortable". The company has independently developed a number of green building technologies, such as constant temperature, humidity and oxygen systems and highly efficient exterior wall insulation systems, to provide residents with a high-quality living environment. Lanson's green residential projects have been widely recognized by the market for their outstanding performance in energy saving, environmental protection and health. In terms of green finance, Lanxess actively explores innovative financing models to provide financial support for green projects. The company has issued green bonds for the development and construction of green building projects. At the same time, Lanson also cooperates with financial institutions to carry out green supply chain finance business to help suppliers solve financing problems and promote the green development of the whole supply chain. In addition, Lanson also

focuses on corporate social responsibility and actively participates in public welfare activities to promote the popularization and dissemination of green building concepts. By organizing green building seminars and conducting green community activities, the company raises public awareness and understanding of green building, creating a good social atmosphere for the sustainable development of the industry.

7.3 Implications of the Cases for the Industry

7.3.1 Enhancing awareness of green transition and building ecosystem aspects

In this case, the enterprise has enhanced the awareness of green transformation among all employees through internal training and external cooperation, so that the green concept runs through all aspects of the enterprise's operation. For the real estate industry as a whole, companies should learn from this experience and make the cultivation of green transition awareness a regular task. Industry associations can organize regular seminars and training courses, invite experts to share the latest green development concepts and trends, and help corporate managers and employees understand the importance and urgency of green transformation[12].

7.3.3 ESG practices and financing aspects

By strengthening ESG practices, the case company improved its ESG rating and thus reduced its debt financing costs. The real estate industry should incorporate ESG practices into its strategic planning and strengthen the management and disclosure of ESG indicators. Industry associations can formulate ESG evaluation standards and guidelines to guide enterprises in ESG practices. Enterprises can improve their ESG performance by improving environmental management, enhancing social responsibility fulfillment, and improving corporate governance.

8 CONCLUSION

This study systematically analyzes the transformation path of China's real estate industry under the synergistic background of the "dual-carbon" strategy and the "housing without speculation" policy, and reveals the dual challenges and opportunities for the industry's low-carbon development. The study finds that the real estate industry is deeply related to the dual-carbon goal, but faces core problems such as the lack of carbon footprint measurement standards, lagging behind in the application of green technologies, increasing financing constraints, and policy adaptation dilemmas. The study proposes a multi-dimensional implementation framework to promote the transformation of the industry by strengthening corporate green awareness, building a carbon-neutral business ecosystem, enhancing carbon accounting capacity through technological innovation, optimizing financing structure by deepening ESG practices, and combining the development of low-carbon building standards and green supply chain management with other policy paths. However, the study is limited by the lack of completeness of carbon emission data, insufficient consideration of regional differences and sample representativeness. In the future, we need to improve the data monitoring system, strengthen the analysis of regional differences, pay attention to the transformation paths of small and medium-sized real estate enterprises, and carry out interdisciplinary research to deepen the theoretical and practical exploration of the economic effects of green technologies, policy incentives, and resource synergistic modes, so as to provide more accurate support for the sustainable transformation of the industry and the realization of the national dual-carbon goal.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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