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China's New Energy Buildings Based on Renewable Energy Technologies

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Abstract. Reducing the energy consumption and carbon emissions of buildings is one of the key research topics nowadays. Researchers have discovered that there are already relevant new energy sources applied in buildings, but the issue of new energy buildings in China still lies in a research gap, lacking a unified understanding. Therefore, this study focuses on new energy buildings in China, while also paying attention to the related cutting-edge application technologies and supporting policies. Through collecting data related to new energy buildings and using methods of literature analysis and case studies, this paper discusses new energy buildings, photovoltaic integration (BIPV) with application prospects, and power storage direct flexible operation technology (PEDF). At the same time, it studies the current existing policies and regulations in China. The research finds that the application of BIPV and PEDF technologies in buildings can increase the proportion of renewable energy, improve the efficiency of the energy system, and play an important role in energy conservation and carbon reduction of buildings. However, these technologies also face challenges such as high costs, lack of technical standards, and imperfect management mechanisms. In terms of policies, China has established a relatively complete new energy policy system, but there is also a lack of specifications for new energy technologies. The research shows that BIPV and PEDF technologies have great application potential, and China's new energy policies still have room for improvement.

Keywords: New energy buildings, BIPV, PEDE, New building policy

1. Introduction

As a major carbon emitter in the world, China has consistently maintained a high level of carbon emissions. Therefore, it is imperative for the government to take measures to reduce carbon emissions. In September 2020, China proposed the dual carbon goals at the United Nations General Assembly [1]. In October 2021, it issued the opinions and action plans for carbon peak and carbon neutrality, completing the top-level design and action deployment [2]. Urban and rural construction is a key area for energy consumption and carbon emissions. In 2022, the energy consumption of buildings and the construction industry across the country reached 2.42 billion tce (accounting for 44.8% of the total national energy consumption, with building operation and construction industry energy consumption accounting for 22.0% and 22.8% respectively) [3]. The development of renewable energy and new energy buildings, as well as reducing reliance on one-time fossil energy,

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are the key paths to lowering building energy consumption and promoting green and low-carbon development.

Renewable energy is an almost inexhaustible source of clean power, featuring core advantages such as zero carbon emissions, wide distribution of resources, and outstanding long-term economic performance. However, it still faces multiple challenges in its application in buildings.

This article conducts a systematic analysis of the current mainstream technologies applied in new energy buildings, and in combination with the review of the policy system in the field of new energy buildings in China, identifies and summarizes the key challenges faced by the development of new energy buildings in our country, and then proposes targeted suggestions for development paths. This article conducts a systematic analysis of the current mainstream technologies applied in new energy buildings, and in combination with the review of the policy system in the field of new energy buildings in China, identifies and summarizes the key challenges faced by the development of new energy buildings in our country, and then proposes targeted suggestions for development paths.

2. New energy buildings and the challenges

2.1. New energy building

New energy buildings refer to buildings where, during the design, construction and operation phases, advanced new energy technologies are fully integrated and renewable energy is efficiently utilized, reducing the use of fossil fuels. This aims to achieve cleaner and lower-carbon energy supply for the buildings, while enhancing their energy utilization efficiency and sustainability.

The Comprehensive Service Center of the Urban and Rural Management Center in Xiong an New Area of Hebei Province is a typical case of ultra-low energy consumption and new energy buildings. The project adopts a steel structure and prefabricated structure system, integrating efficient insulation (300mm rock wool strips on the exterior walls, with a heat transfer coefficient K = 0.130 W/(m²·K)) High-performance exterior windows (wooden frame structure windows, K = 0.8 W/(m²·K)), airtight design ($N_{50} \leq 0.54\ h^{-1}$), and an efficient heat recovery ventilation system (sensible heat recovery efficiency 75.76%) [4].

In terms of the utilization of new energy, the project is equipped with 300 photovoltaic modules, generating approximately 110,376 kWh of electricity annually. Combined with the ground-source heat pump system (with an energy efficiency 40% higher than traditional air conditioners), the annual primary energy consumption of the building is reduced to 42.69 kWh/(m²·a), achieving a 63.1% energy saving compared to the reference building (115.69 kWh/(m²·a)), and the proportion of renewable energy in total energy consumption is approximately 54% [4]. This case, through quantitative energy consumption simulation and technical economic analysis, verified the feasibility of applying renewable energy technologies in buildings (Figure 1). The combination of renewable energy technologies and buildings will become the preferred choice for building emission reduction and energy conservation.

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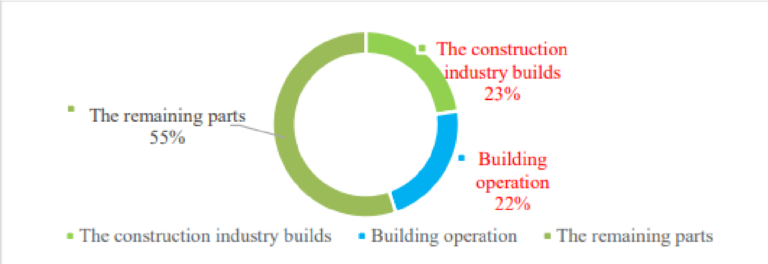

Figure 1. China's energy consumption in 2022 (photo/picture credit: original)

2.2. The main challenges

New energy buildings face various challenges. Firstly, they need to integrate renewable energy technologies with the building systems themselves to ensure that the building's own functions are met while also meeting the working conditions required for the application of new energy technologies. For example, in regions like Saudi Arabia with high temperatures throughout the year, the temperature of the photovoltaic components in the photovoltaic-integrated building system (BIPV) can reach 60-70 degrees Celsius, which significantly affects the power generation efficiency. To address this issue, relevant improvements have been made to the BIPV systems in the Saudi Arabian region. Advanced cooling technologies such as phase change materials (PCM) have been used in the system, which can reduce the temperature of the photovoltaic components by 10-15 degrees Celsius under high temperatures, thus enabling BIPV to adapt to such special environments [5]. Secondly, the application of new energy technologies also faces high initial investment costs and long-term maintenance costs. Compared to traditional buildings in Saudi Arabia, the BIPV projects cost an additional 25%-50%. Although the long-term use can recover the costs, the high initial investment significantly reduces its promotional potential [5]. Moreover, new energy buildings also face problems of incomplete policies and low market expectations, which to some extent affect the promotion of new energy technologies. For example, Saudi Arabia lacks stimulus policies for new energy buildings, and the local new energy building market started relatively late, which greatly reduced the enthusiasm of project investors and thus affected the promotion of new energy buildings. Finally, the social and public recognition of new energy buildings is insufficient, which also limits the promotion of new energy buildings. In the NEOM project in Saudi Arabia, although cases related to the application of BIPV technology have demonstrated its application value and feasibility, additional education and construction demonstration projects are still needed to change public perception and increase public acceptance [5]. In conclusion, the challenges faced by new energy buildings still need to be overcome through the implementation of a series of measures. It is necessary to continuously improve technical efficiency, reduce investment costs, and continuously enhance public recognition to gradually promote new energy buildings.

2.3. Building integrated photovoltaics

Building-integrated photovoltaic (BIPV) technology is a current popular new energy technology that can be widely applied in buildings, significantly changing the original energy structure of buildings and promoting the development of sustainable buildings. The application of BIPV in buildings not only provides the daily electricity needed for buildings but can also serve as the building's own enclosure structure without affecting its aesthetics and practicality requirements. According to the research of Zhu et al., BIPV technology can simultaneously meet the aesthetic and basic functional

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requirements of buildings through design, provide considerable power generation, and achieve its optimal performance [6]. Qahtan et al. proposed that in the application of BIPV technology in buildings in China, although its initial cost is higher than that of traditional technologies by 25%-50%, from a long-term perspective, considering its savings in electricity costs and reduction in its own maintenance costs, BIPV technology has high economic feasibility [7]. Meanwhile, according to the research of Wang et al., the investment payback period of BIPV technology application cost is 4 to 7 years, which also confirms its economic feasibility [8].

The application of BIPV technology significantly reduces buildings' dependence on traditional fossil energy. According to the data of the International Energy Agency, buildings applying BIPV technology can reduce carbon emissions by up to 50% of the original amount each year, thereby achieving green and low-carbon buildings [9]. Siddiqui et al. studied that the promotion and application of BIPV technology can effectively reduce the urban heat island effect and improve the urban microclimate to a certain extent [10]. Relevant new energy building cases include the Shanghai Global Financial Center project, which adopted BIPV technology, achieving energy conservation and carbon reduction of the building itself, and also increasing public recognition of new energy technologies. In conclusion, BIPV technology has demonstrated significant superiority in multiple aspects such as technology, environment, and economy in new energy buildings. At present, it still has broad application prospects. Future research should focus on reducing the application cost of the technology, improving the power generation efficiency of the technology, and thereby promoting the use of BIPV technology in buildings.

2.4. Photovoltaic-storage-direct-flexibility technology

Photovoltaic Direct Flexibility Technology (PEDF) is also an important new energy building technology. This technology integrates photovoltaic power generation, energy storage, power distribution, and load management into a single system, thereby improving the energy efficiency of buildings. The PDEF system can ensure stable supply of building electricity during peak hours and reduce reliance on grid power supply. For example, according to the research conducted by Wu et al., in some new energy building projects in southern China, the use of PDEF technology has achieved an energy self-sufficiency rate of up to 80%, improving the energy independence of buildings [11]. The flexible load management of PEDF technology can better solve the problem of intermittent renewable energy. According to the research by Wu et al., the PEDF technology can perform intelligent load management by optimizing the operation time of various equipment in the building, reducing unnecessary electricity consumption, and thereby improving energy utilization efficiency [11]. In summary, the application of PEDF technology in new energy buildings has solved the problems of energy storage and energy configuration in new energy buildings, and significantly improved the independence of building energy supply. In the future, it is still necessary to continuously promote the iteration of PDEF technology and apply it more in new energy buildings.

3. New energy building policy

3.1. Present situation of China

Over the past several decades, China's policies on new energy buildings have undergone significant development, forming a relatively complete policy system. The policies within this system have played a crucial role in promoting the green development transformation of the Chinese construction industry. China has established a framework for the coordinated operation of laws and policies. At

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the legal level, the Renewable Energy Law provides the fundamental basis for the formulation of policies related to new energy buildings, ensuring the basic rights of applying new energy technologies in new energy buildings. At the planning level, the country has incorporated the development of new energy buildings into the overall strategy for China's carbon peak and carbon neutrality, which is reflected in the policies emphasizing the need to increase the proportion of renewable energy in the energy structure of buildings and to fully utilize renewable energy in new construction. In terms of standards and norms, for example, relevant evaluation systems have been established in the green building assessment standards, which regulate the construction of new energy buildings and ensure that new energy buildings meet certain quality and performance standards.

The development of China's new energy building policies has three major trends. Firstly, it has shifted from encouragement and guidance to the formulation of mandatory standards, gradually raising the requirements for buildings. Secondly, it has moved from a single technology to an integrated system, emphasizing the development of energy systems and promoting the transformation and development of buildings. Thirdly, it has progressed from expanding building scale to improving the quality and efficiency of new energy buildings, attaching importance to the entire life cycle of construction projects, and continuously establishing and improving systems; green electricity, carbon trading markets, to promote the green and low-carbon development of buildings.

Although the policy system for new energy buildings in China has been continuously improved and has achieved remarkable results in promoting the development of new energy buildings, there are still many challenges in the implementation process Technically, the standards for integrating new energy with building design are not yet fully developed, and the compatibility of multi-energy complementary systems is insufficient, which hinders the efficient operation and overall performance of the new energy system in buildings. Economically, the initial investment cost of new energy buildings is high and the return period is long. Coupled with the unclear grid connection and consumption policies in some regions, the internal driving force of the market is relatively weak, and the investment enthusiasm of enterprises and property owners has been affected. In terms of management, there is insufficient synergy between the renovation of existing buildings and the application of new energy sources, and there is a lack of effective coordination mechanisms and policy measures. At the same time, the long-term operation and maintenance mechanism and the full-process supervision are absent, making it difficult to ensure the long-term stable operation of new energy buildings.

3.2. Policy pilot program

In terms of management, there is insufficient synergy between the renovation of existing buildings and the application of new energy sources, and there is a lack of effective coordination mechanisms and policy measures. At the same time, the long-term operation and maintenance mechanism and the full-process supervision are absent, making it difficult to ensure the long-term stable operation of new energy buildings. Shenzhen has passed legislation to enforce collaboration with the industrial chain to promote the large-scale development of new energy buildings. The Green Building Regulations of the Shenzhen Special Economic Zone stipulate that the photovoltaic coverage rate of new public buildings should not be lower than 50%. As of 2023, the actual completion rate reached 62%, exceeding the target. A total of 12 photovoltaic storage direct flexible power demonstration projects have been built in the city. The representative project, Shenzhen Future Building, has achieved an energy self-sufficiency rate of over 70% for building energy consumption (while traditional buildings have only 10% to 15%), with an annual carbon reduction of 100,000 tons [12].

Hangzhou has promoted the large-scale application of building-integrated photovoltaics (BIPV) through special plans and subsidy policies. The pilot program for photovoltaic building integration in Hangzhou requires that the proportion of rooftop photovoltaic installations in newly-built industrial buildings and large public buildings should not be less than 40%. Additionally, for projects using BIPV technology, a one-time subsidy of 30 yuan per square meter will be provided (up to a maximum of 1 million yuan). During the pilot period from 2022 to 2023, Hangzhou added 230 BIPV projects, with a total installed capacity of 210 million watts, accounting for 35% of the city's total new photovoltaic installation capacity during the same period (higher than the national average of 20%); each commercial complex BIPV project achieved an 8% increase in power generation efficiency through integrated design of photovoltaic facades, while reducing the cost of exterior materials by approximately 12% [13].

The two approaches respectively from the perspectives of carbon reduction rigid targets and market-driven efficiency have provided regionally tailored practical models for different regions with diverse resource endowments and demands across the country. This demonstrates the crucial supporting role of local pilot projects in promoting new energy buildings under the national dual carbon strategy.

3.3. Policy suggestion

Firstly, in terms of China's new energy policies, there is a need to strengthen policy implementation and supervision. Local governments should enhance the enforcement of building energy-saving policies to ensure that these policies take root and bear fruit. For instance, research has shown that the network embedding of subsidiaries of emerging economies' multinational enterprises is conducive to policy implementation [14]. Local governments can establish similar network embedding mechanisms to enhance communication with enterprises and communities, thereby improving the efficiency of policy implementation. The government and relevant departments should promote technological innovation, increase investment in energy-saving technology research and development, and encourage technology promotion through policy incentives. The government can take measures such as financial subsidies and tax incentives to encourage enterprises to conduct research on new energy technologies and apply them, thereby promoting technological progress. The government also needs to improve the policy framework, formulate systematic and coordinated policies, and reduce conflicts and contradictions among policies. At the same time, the government should continuously study cases related to new energy buildings, absorb experience, optimize supporting policies, and achieve the effectiveness of policies. The government should also pay attention to cross-departmental collaboration, establish coordination mechanisms to promote communication among departments, strengthen cooperation among departments, and ensure the implementation of policies. Zhang Fengbing et al. have shown that cross-departmental collaboration can better ensure the implementation of policies [15]. The government can establish an information sharing platform to promote cooperation among departments and form a policy synergy.

4. Conclusion

This research focuses on the field of new energy buildings in China, concentrating on renewable energy technologies and policy systems. The core findings can be summarized in three aspects: Firstly, the technical feasibility has been verified. The two key technologies of building-integrated

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photovoltaics and photovoltaic storage direct-flex power supply have been proven through practice to effectively enhance the utilization rate of renewable energy in buildings, reduce carbon emissions, and balance economic and functional aspects. They also have the potential for promotion. Secondly, a policy framework has been established to support them China has established a framework that integrates laws, planning and standards. Through laws, it clarifies the status; through planning, it anchors strategic goals; through standards, it regulates construction requirements. Policy trends have shifted from encouragement to mandatory measures, from a focus on a single technology to system integration, and from scale expansion to quality improvement and efficiency enhancement. Thirdly, the constraints are prominent. This requires the formulation of more detailed technical standards, as well as the improvement of integrated design and compatibility requirements; the optimization of incentive mechanisms, by providing subsidies and tax incentives to reduce investment pressure, and integrating market mechanisms to enhance economic efficiency. This requires the formulation of more detailed technical standards, as well as the improvement of integrated design and compatibility requirements; the optimization of incentive mechanisms, by providing subsidies and tax incentives to reduce investment pressure, and integrating market mechanisms to enhance economic efficiency. Strengthen cross-departmental collaboration and establish an information sharing and collaboration platform; enhance full-process supervision, and improve operation and monitoring mechanisms. Future research can focus on optimizing technological adaptability and designing precise policy tools, and summarize the local pilot experiences in China to provide references for global building low-carbon transformation, and contribute to the realization of the dual carbon goals.

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