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RESEARCH ON THE PATHWAYS AND STRATEGIES FOR ZERO-CARBON CAMPUS TRANSITION BASED ON INTELLIGENT MODELS

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Abstract:*With the global emphasis on sustainable development and the promotion of the "dual carbon" goal, zero carbon campus construction has become an important task in the field of education. This article comprehensively analyzes four papers and explores campus zero carbon construction based on smart models.By studying smart energy management, green building design, smart streetlight application, and related technology integration, effective paths and strategies for campus zero carbon construction are proposed, aiming to provide theoretical basis and practical guidance for achieving sustainable campus development.*

Keywords : *Zero carbon campus, Sustainable development,Energy management,Green construction*

1 Introduction

1.1 Research Background and Significance

Amidst the increasingly severe global climate crisis, phenomena such as glacier melting and rising sea levels are intensifying, posing unprecedented threats to ecosystems. As an important part of society, the issue of carbon emissions in campuses cannot be ignored. The campus is densely populated, with frequent teaching and living activities, and energy consumption involves multiple aspects such as electricity, heating, cooling, and transportation. From the perspective of ecological protection, reducing campus carbon emissions can directly reduce the demand for natural resources and the emission of pollutants, which helps maintain local ecological balance. From the perspective of fulfilling social responsibility, campuses are the cradle for cultivating future social pillars, actively promoting zero carbon transformation, and being able to convey green environmental protection concepts to students, faculty, and all sectors of society, playing a good exemplary role and inspiring more groups to participate in actions to address climate change. The transition to a zero carbon campus is urgent, which is not only a necessary requirement to address the global climate crisis, but also an important path for campuses to achieve sustainable development and demonstrate social responsibility.

1.2 Current Research Status at Home and Abroad

Research on zero carbon campuses has achieved certain results both domestically and internationally. In terms of theory, scholars have conducted in-depth discussions on the connotation, characteristics, and construction path of zero carbon campus, providing theoretical support for the construction of zero carbon campus. For example, Mao Xuedong pointed out that the construction of low-carbon campuses should be guided by the scientific outlook on development, advocating low-carbon concepts, and promoting sustainable development of campuses. In practice, many universities actively carry out pilot projects for zero carbon campus construction, accumulating rich experience in building energy conservation, energy management, and resource recycling. For example, the Beckenfeld campus of Trier University of Applied Sciences in Germany has achieved "zero emissions" of carbon dioxide from electricity and heat supply by developing renewable energy technologies; Tongji University focuses on energy conservation and emission reduction in campus construction, and has created a number of green and low-carbon projects. However, there are still some shortcomings in existing research, some of which lack systematicity and depth, and the research on key technologies and management models in zero carbon campus construction is not comprehensive enough; In practice, the construction of zero carbon campuses faces problems such as high technical application difficulty, high cost, and low participation of teachers and students. The application research of intelligent mode in zero carbon campus construction is still in its infancy, and related technologies and strategies need further exploration and improvement. Therefore, strengthening research on zero carbon campus construction under intelligent mode can help fill existing research gaps, overcome practical difficulties, and promote the development of zero carbon campus construction to a higher level.

1.3 Research Methods and Innovation Points

This study comprehensively utilizes multiple research methods. Through literature research, this study aims to review the relevant theories and practical cases of zero carbon campus construction both domestically and internationally, providing a solid theoretical foundation and practical experience reference for research. The field research method enables in-depth research, obtaining first-hand information, understanding the current situation of campus carbon emissions and the problems faced by zero carbon construction, and proposing targeted solutions. The case analysis method selects typical zero carbon campus cases at home and abroad for detailed analysis, summarizes successful experiences and shortcomings, and provides useful references for other campuses.

The innovation of this study is mainly reflected in two aspects. One is the integration and innovation of multiple technologies, deeply integrating cutting-edge technologies such as artificial intelligence and big data into the construction of zero carbon campuses. Utilizing artificial intelligence to optimize energy management systems, achieving precise prediction and intelligent regulation; Big data technology analyzes campus carbon emission data to provide scientific basis for decision-making. Through the synergistic effect of these technologies, the intelligence level and overall effect of campus zero carbon construction can be improved. The second is personalized strategy innovation, fully considering the differences in geography, scale, and disciplinary characteristics of different campuses, and formulating zero carbon construction strategies that are suitable for them. For example, developing and utilizing renewable energy based on the surrounding resources of the campus; Based on disciplinary advantages, carry out research and application of low-carbon technologies; Design personalized low-carbon education and incentive mechanisms to meet the needs of teachers and students, increase their participation, and make the construction of a zero carbon campus more targeted and effective.

2 The connotation and theoretical basis of a zero carbon campus

2.1 Definition of Low Carbon Campus Concept

Zero carbon campus refers to the goal of achieving a balance or approaching zero carbon emissions and absorption through a series of energy-saving and emission reduction measures throughout the entire lifecycle of the campus. It covers a wide range of aspects, including the planning, design, construction, operation, and maintenance of campus buildings, as well as various activities such as teaching, research, management, and daily life on campus. Compared to low-carbon and carbon neutral campuses, zero carbon campuses have stricter requirements. Low carbon campus focuses on reducing carbon emission intensity, energy consumption, and greenhouse gas emissions; Carbon neutral campuses emphasize the balance between carbon emissions and carbon absorption, but the implementation methods are relatively broad. A zero carbon campus not only requires achieving carbon neutrality, but also strives to minimize carbon emissions through various means, even approaching zero emissions. For example, in terms of energy supply, zero carbon campuses prioritize the use of renewable energy sources such as solar, wind, hydro, etc., reducing reliance on traditional fossil fuels; In architectural design, emphasis is placed on using energy-saving materials and technologies to improve the energy efficiency of buildings; In campus management, measures such as green travel, garbage classification, and resource recycling are implemented to reduce carbon emissions from various aspects.

2.2 Analysis of Research Related Theories

The theory of sustainable development provides macro guidance for the construction of zero carbon campuses. This theory emphasizes the coordinated development of economy, society, and environment, requiring the ability of future generations to meet their own needs while meeting the needs of the present.

In the construction of a zero carbon campus, following the theory of sustainable development means balancing the relationship between teaching and research, teacher-student life, and environmental protection in the process of campus development. For example, in campus planning, a reasonable layout of teaching areas, living areas, and ecological areas should be made to ensure that the same teaching areas, living areas, and ecological areas have complete campus functions, while reducing damage to the natural environment; In terms of resource utilization, advocating the circular economy model, improving resource utilization efficiency, reducing waste emissions, and promoting low-carbon campus construction are technical measures, such as promoting the use of new energy and deepening building energy conservation.

The theory of circular economy is an important support for the construction of zero carbon campuses. The core of circular economy is the "3R" principle, which refers to reducing, reusing, and recycling. In campus construction, the application of circular economy theory can be approached from multiple aspects. In the material procurement process, priority should be given to selecting environmentally friendly and recyclable products to reduce the use of disposable items; In terms of campus facility management, strengthen the maintenance and updating of equipment, devices, etc., extend their service life, and improve the efficiency of resource reuse; For waste, establish a comprehensive classification and recycling system to achieve resource recycling. For example, recycling waste paper, plastic bottles, and other materials on campus and processing them into new products; After treating the sewage, it can be used for campus greening irrigation or toilet flushing.

The theory of energy management provides a theoretical basis for optimizing energy allocation in zero carbon campuses. This theory systematically manages the production, transmission, distribution, and use of energy to improve energy efficiency, reduce energy costs, and minimize environmental impact. In the construction of a zero carbon campus, the application of energy management theory includes energy auditing, energy monitoring, energy-saving technology transformation, and other aspects. Through energy auditing, comprehensively understand the campus energy consumption situation, identify the links and reasons for energy waste; Utilize energy monitoring systems to monitor energy usage in real-time and provide data support for energy management decisions; Promote energy-saving technology transformation, such as adopting high-efficiency energy-saving equipment, optimizing energy supply systems, etc., to improve energy utilization efficiency. These theories are interrelated and complementary, providing a solid theoretical foundation for the construction of a zero carbon campus, guiding the campus to take effective measures in various aspects, achieve the reduction of carbon emissions, and achieve zero carbon goals.

3 Current Status and Challenges of Campus Carbon Emissions

3.1 Analysis of Major Carbon Emission Sources

Campus carbon emissions are widely distributed in multiple core areas such as teaching, living, catering, and transportation. In teaching activities, multimedia teaching equipment and laboratory instruments consume significant power during long-term operation, especially in science and engineering laboratories. Large equipment such as high-precision electron microscopes and professional experimental devices have high power and frequent use, and their carbon emissions should not be underestimated. In terms of daily life, there are various electrical appliances in student dormitories. Heating equipment in winter, air conditioning and cooling in summer, as well as electricity consumption for daily computers, lighting fixtures, etc., generate a large amount of carbon emissions. With the improvement of living quality, the number and duration of electrical appliances increase, and carbon emissions show an upward trend.

The carbon emissions of the catering sector are concentrated in the food processing and cooking process. The burning of fossil fuels in stoves releases carbon dioxide, and processes such as food transportation and tableware cleaning and disinfection indirectly generate carbon emissions, such as energy consumption during long-distance cold chain transportation of food and steam energy consumption during centralized tableware disinfection. The carbon emissions from transportation mainly come from the fuel consumption of commuting vehicles on campus and the parking and short distance travel of private vehicles by teachers and students. The larger the campus scale and the more dispersed the functional zones, the more prominent the carbon emissions from transportation.

3.2 Effectiveness and limitations of existing carbon reduction measures

The school has implemented a series of energy-saving measures, such as installing energy-saving lamps in teaching and office buildings to reduce lighting energy consumption to a certain extent; Some buildings use exterior wall insulation materials to reduce heat loss during winter heating. However, the effectiveness is still constrained by multiple factors. In terms of energy structure, traditional thermal power is highly dependent, there are insufficient renewable energy generation facilities on campus, and the utilization of solar and wind energy is limited to small-scale demonstration projects, without forming economies of scale, making it difficult to fundamentally reverse the high carbon energy supply situation. In terms of management, energy monitoring is rough and relies heavily on manual meter reading and statistics, resulting in poor data timeliness and low accuracy, making it difficult to detect energy consumption anomalies in a timely manner.

The lack of dynamic optimization in equipment operation management, such as the air conditioning system being switched on and off according to a fixed schedule, without integrating intelligent control of indoor and outdoor temperature and humidity with real-time personnel distribution, can easily lead to energy waste. At the same time, the incentive mechanism for teachers and students to participate in carbon reduction is not perfect, and energy-saving behaviors rely more on self-awareness, lacking effective guidance and reward measures, which limits the overall depth and breadth of carbon reduction. This highlights the urgent need for the deep integration of intelligent models into campus energy management and carbon reduction actions, in order to break through existing bottlenecks and improve carbon reduction efficiency and effectiveness.

4 Key Technologies Empowering Campus Zero Carbon with 4 Intelligent Modes

4.1 Artificial Intelligence Optimization Algorithm

AI technology deeply reshapes the logic of campus energy management. Train models using multi-source data such as historical energy consumption data, meteorological data, and campus activity schedules to accurately predict energy demand. Taking the campus lighting system as an example, AI analyzes seasonal changes, changes in day and night duration, and personnel flow patterns, intelligently adjusts the on-off time and brightness of lighting fixtures, and avoids excessive lighting while ensuring lighting needs; The air conditioning system predicts the cooling and heating load based on indoor and outdoor temperature and humidity, as well as personnel density, dynamically allocates cooling and heating energy, and reduces equipment idle time and energy consumption. Through continuous learning and optimization, AI continuously improves prediction and scheduling accuracy, achieves dynamic balance between energy supply and demand, effectively reduces campus carbon emissions, and becomes the core driving force for the construction of intelligent zero carbon campuses.

4.2 Big data-driven decision-making

Massive campus energy consumption data is deeply mined through big data technology, unleashing enormous value. At the level of campus planning, analyzing the energy consumption characteristics of different functional areas provides scientific basis for the site selection, layout, and energy facility configuration of new buildings. For example, when planning the relative position between teaching areas and living areas, minimizing commuting energy consumption should be considered; In terms of event coordination, based on the time, scale, and energy consumption requirements of large-scale exams, academic conferences, sports events, etc., reasonable arrangements for venue and equipment usage periods are made to optimize energy allocation. Big data mining can also discover hidden energy consumption related factors, such as the coupling relationship between the use of equipment in different academic laboratories and energy consumption, which can help with targeted energy-saving renovations, comprehensively improve campus energy utilization efficiency, and provide accurate navigation for campus zero carbon transformation.

5 Campus Zero Carbon Construction Strategies Based on Intelligent Mode

5.1 Intelligent Energy Management Strategy

By deploying advanced energy management systems (EMS), campuses can monitor and control energy consumption in real-time, optimize energy allocation, and improve energy utilization efficiency. The system should have data collection, analysis, and prediction functions, and be able to automatically adjust energy supply based on the energy demand of the campus and the availability of renewable energy. Using artificial intelligence algorithms to predict energy demand, combined with weather forecasts and historical data, optimize the generation and storage of renewable energy sources such as solar and wind power. The intelligent energy management system should also be integrated with the building management system (BMS) and traffic management system (TMS) to achieve collaborative optimization of energy. Through this approach, campuses can reduce their dependence on traditional fossil fuels, lower carbon emissions, and improve the reliability and stability of energy supply.

5.2 Intelligent Upgrade of Green Buildings

Using high-performance building materials and equipment, such as energy-saving windows, high-efficiency insulation materials, intelligent lighting systems, and ground source heat pumps. By using Building Information Modeling (BIM) technology, the full lifecycle management of buildings can be achieved, from design, construction to operation and maintenance, ensuring the green performance of buildings. The intelligent building management system (BMS) can monitor the energy consumption and environmental parameters of buildings in real time, such as temperature, humidity, carbon dioxide concentration, etc., and automatically adjust the operating status of buildings based on preset parameters, achieving efficient energy utilization and indoor environmental comfort. The intelligent upgrade of green buildings should also include rainwater collection and reuse systems, solar hot water systems, etc., further reducing dependence on traditional energy and lowering carbon emissions.

5.3 Intelligent Transportation and Logistics Planning

By optimizing the transportation network on campus, reducing the use and congestion of vehicles, and lowering the carbon emissions generated by transportation. We can construct bicycle lanes and pedestrian walkways to encourage teachers and students to use non motorized vehicles for travel; Promote electric vehicles and buses to reduce exhaust emissions; And implement an intelligent transportation management system. The campus logistics system should also undergo intelligent upgrades, using electric logistics vehicles and intelligent warehouse management systems to improve logistics efficiency, reduce energy consumption and carbon emissions. Through these measures, the campus can achieve zero carbon goals in the transportation sector, while improving the travel experience of teachers and students and the environmental quality of the campus.

6 Analysis of the Social and Economic Benefits of a Zero Carbon Campus

6.1 Social benefits

The zero carbon campus, as an innovative educational model, provides a demonstration of sustainable development for society. It achieves zero carbon goals through intelligent technology and green buildings, providing valuable experience and models for other schools and educational institutions to learn from. This educational demonstration can stimulate the attention and participation of all sectors of society in sustainable development, and promote the green transformation of society.

A zero carbon campus not only has an impact on the campus itself, but also has a radiation effect on the surrounding communities. Through cooperation and communication with the community, the campus can share its green technology and management experience, helping the community improve energy efficiency and reduce carbon emissions. It can also provide green employment opportunities for the community, promote economic development and social stability.

The zero carbon campus provides students with a platform to practice and learn about sustainable development. By participating in campus zero carbon construction, students can learn advanced intelligent technology and green building knowledge, and cultivate their innovation and practical abilities. These skills and knowledge will provide strong support for students' future employment and career development, while also cultivating a group of talents with green awareness and innovation ability for society.

6.2 Economic benefits

A zero carbon campus can significantly reduce energy consumption and operating costs by adopting renewable energy and energy-saving technologies. The utilization of renewable energy sources such as solar and wind can reduce reliance on traditional fossil fuels and lower energy procurement costs. Intelligent energy management systems and green building technologies can improve energy efficiency, reduce energy waste, and further lower operating costs. Zero carbon campus can also obtain additional economic benefits through carbon trading and green certification, improving the economic efficiency of the campus.

Zero carbon campus, as an innovative educational model and a model of sustainable development, has high social and brand value. Through the construction of a zero carbon campus, the campus can enhance its visibility and reputation, attract more students and teachers, and improve its competitiveness and attractiveness. The construction of zero carbon schools can enhance the campus's visibility and reputation, attract more students and teachers, and improve the competitiveness and attractiveness of the school. A zero carbon campus can also provide green technology and management experience for society, promote sustainable development opportunities, and thus gain higher social recognition and value added.

The construction of a zero carbon campus can drive the development of related industries and form an industrial linkage effect. The renewable energy industry, intelligent technology industry, green building industry, etc. can all benefit from the construction of zero carbon campuses. Through cooperation with these industries, campuses can promote technological innovation and industrial upgrading, drive the development of related industries, and create more employment opportunities and economic benefits for society.

7 Conclusion and Prospect

This study focuses on the campus zero carbon path based on smart models, clarifies the key significance of zero carbon campuses in the global climate crisis, reviews the current research status at home and abroad, comprehensively applies multiple research methods, and has innovative points in multi technology integration and personalized strategies. In depth analysis of its connotation and theoretical basis, analysis of campus carbon emission sources and existing carbon reduction limitations, introduction of key technologies such as artificial intelligence and big data, as well as construction strategies for intelligent energy, buildings, transportation, etc., elaborating on social and economic benefits. Research has shown that smart models can effectively assist in zero carbon campus construction, promote sustainable development, and bring comprehensive benefits.

In the future, it is necessary to deepen the application of intelligent technologies, such as optimizing AI algorithms to improve energy management accuracy and expanding big data application scenarios; Improve the standards and regulatory system for zero carbon construction on campus, and promote standardization in practice; Strengthen inter school and school enterprise cooperation and exchange, accelerate technological innovation and experience sharing; Continuously enhance the participation of teachers and students, carry out diverse low-carbon education activities, comprehensively promote the zero carbon construction of campuses to a new height, and provide stronger support for the low-carbon transformation of society.

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