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Strategies for Developing Low-Carbon University Campuses in China within the Context of Sustainable Development

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Abstract**—***This study explores strategies for the construction of low-carbon campuses in Chinese universities under the framework of sustainable development and finds that there is a significant lack of awareness and participation among college students in low-carbon education and practice. Through a questionnaire survey of college students in Hubei Province, the study analyzes students' awareness, attitudes, and behaviors regarding low-carbon campuses, revealing issues faced by universities in promoting the low-carbon transition, such as inadequate infrastructure, insufficient integration of educational content, and limited student participation. In response to these challenges, the study proposes several feasible suggestions, including strengthening low-carbon infrastructure (such as the introduction of clean energy and optimization of intelligent power systems), integrating low-carbon education into the curriculum system, promoting experiential learning through green activities, and creating a campus culture of environmental protection. The study believes that by cultivating college students' low-carbon behavior habits and environmental awareness, universities can not only contribute to the achievement of the "dual carbon" goals but also become a key force in promoting sustainable development throughout society. This study provides theoretical support and practical guidance for the transition of universities to sustainable campuses and offers a reference for other educational institutions to achieve low-carbon development goals.*

Keywords**— college students, low-carbon awareness, universities**

I. INTRODUCTION

In the face of increasingly severe global climate change and environmental degradation, promoting sustainable development has become a global consensus and action plan. Universities, as the training grounds for future leaders of society, not only bear the heavy responsibility of promoting sustainable social development but also shoulder the dual mission of enhancing students' environmental awareness. By constructing low-carbon campuses, universities can not only effectively reduce their own carbon emissions and achieve green transformation but also influence society through their exemplary role, accelerating the dissemination of sustainable development concepts. In China, in response to the national "dual carbon" targets (carbon peaking and carbon neutrality), the Ministry of Education encourages universities to actively promote low-carbon transformation by adopting various measures such as promoting green buildings, optimizing energy management, and advocating low-carbon lifestyles, thereby becoming a driving force for environmental education. This practice is not only an important measure for universities to achieve the "dual carbon" targets but also provides students with a real-life environment to practice low-carbon principles, enabling them to gradually cultivate green behaviors in their daily lives and lay the foundation for transmitting environmental

awareness in their future careers and lives (Aleixo et al., 2021).

In the context of sustainable development, this study systematically explores the path for constructing low-carbon campuses in universities, focusing on the pivotal role of students in this endeavor. The research objectives include: (1) Assessing students' awareness and participation in the construction of low-carbon campuses through questionnaires, and combining data analysis to deeply understand their attitudes towards low-carbon campuses; (2) Analyzing the obstacles and challenges faced by universities in low-carbon construction from an empirical perspective and proposing targeted improvement suggestions. The findings of this study not only provide practical application value for the low-carbon transformation of universities but also offer valuable insights for Chinese universities and other educational institutions in achieving the "dual carbon" targets.

II. LITERATURE REVIEW

In the realm of carbon sequestration and carbon source management, researchers have proposed various innovative methods to support carbon management in university campuses. Park and Um (2018) utilized drones and visible light spectroscopy technology to identify and differentiate carbon sinks from carbon sources within university campuses, providing a new approach for precise carbon management. Tonietto et al. (2021), based on the case of the University of Michigan, introduced a scalable method to estimate campus carbon storage and biological carbon sequestration capacity, demonstrating a pathway to achieve campus carbon neutrality. Dadhich et al. (2022) focused on the carbon sequestration of campus trees, developing a method to quantify carbon sequestration in campus trees, providing a scientific basis for carbon sink management. In terms of carbon footprint management, Robinson et al. (2018) analyzed carbon footprint management practices in universities through case studies and proposed a universal carbon footprint standard applicable to campuses, providing a framework for quantifying carbon emissions. Liu et al. (2021), taking China University of Water Resources and Electric Power as an example, analyzed carbon management issues at the campus scale from the perspective of the water-energy-carbon nexus, revealing the impact of water resource utilization on carbon emissions.

In optimizing campus energy structures and green building management, researchers have also proposed diversified strategies. Li et al. (2023) combined persuasive technology with campus energy representatives to propose a new strategy to enhance campus energy conservation and carbon reduction. Gabrielli et al. (2020) provided tool support for optimizing energy structures in low-carbon campuses by developing a multi-objective planning model, while Gorgulu and Kocabey (2020) conducted an energy efficiency assessment of campus external lighting systems and proposed energy-saving strategies to further reduce carbon emissions. In the context of green buildings and lifecycle management, Del Borghi et al. (2021) compared zero-energy building designs between European and American universities, exploring pathways to achieve carbon-neutral buildings in different regions. Legorburu and Smith (2020) introduced observational data into energy models during the early design stages of campus buildings, analyzing lifecycle carbon emissions and costs, providing a new perspective for low-carbon building design. Additionally, Boharb et al. (2022) developed a feedback system to support energy conservation in campus residential buildings, further reducing carbon emissions. In terms of campus transportation and smart energy systems, Wang et al. (2020) compared the carbon footprints of bike-sharing and public transportation systems through lifecycle assessment methods, providing a reference for low-carbon transportation. Kourgiozou et al. (2021) reviewed research on smart energy systems in the UK higher education sector, proposing scalable pathways to achieve net-zero carbon emissions, emphasizing the crucial role of smart energy systems in the construction of low-carbon campuses.

These studies reveal that constructing low-carbon campuses is a multifaceted and interdisciplinary process encompassing energy management, carbon footprint quantification, green building design, and behavioral change. They underscore that achieving low-carbon campuses requires not only technological innovation but also robust policy support, cultural evolution, and behavioral transformation. By providing a solid theoretical foundation and practical examples, these studies serve as valuable references for advancing future efforts in low-carbon campus development.

III. RESEARCH METHODS

This study focuses on university students in Hubei Province as its research subjects, using convenience sampling to collect 101 valid questionnaire responses. Data analysis is conducted using SPSS software. The reliability of the questionnaire is first evaluated through the Cronbach's Alpha coefficient, while its validity is assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity.

Following this, cluster analysis is performed to classify respondents into three groups based on their low-carbon awareness and behavioral characteristics. This categorization forms the basis for a deeper examination of differences in low-carbon awareness among university students, providing targeted insights to address key challenges and develop countermeasures for constructing low-carbon campuses.

IV. RESEARCH RESULTS

4.1 Reliability and validity analysis of the questionnaire

As shown in Table 1, the questionnaire achieved a Cronbach's Alpha coefficient of 0.912, exceeding the threshold of 0.7, indicating an acceptable level of reliability.

Table. 1: Questionnaire Reliability Analysis

Cronbach's Alpha Coefficient	Terms
0.912	33

Table. 2: Questionnaire Validity Analysis

KMO sample appropriateness measure		0.819
Bartlett sphericity test	Approximate chi-square	2274.671
	Degree of freedom	528
	Significance (P-value)	<0.001

The KMO value of this questionnaire is greater than 0.5 (Table 2), and the significance of the Bartlett sphericity test is less than the p-value, indicating that the scale is suitable for subsequent analysis.

4.2 Basic Information of Respondents

This survey primarily focused on basic information about the respondents, such as gender, educational stage, and related experiences. The survey revealed that 58.41% of respondents clearly stated they had never taken courses related to low-carbon campuses or low-carbon education, and 62.38% indicated they had never participated in activities promoting low-carbon education, lacking any relevant experiences. This situation clearly shows that there is a significant gap in the important aspect of low-carbon education among university students that cannot be ignored. In the face of this pressing issue, schools should take certain measures to actively and positively guide students in developing good living habits and fostering a low-carbon environmental awareness. Schools can integrate low-carbon education content into the curriculum, such as setting up dedicated courses on low-carbon environmental protection or combining the concept of low-carbon with related subjects. At the same time, they should actively organize activities promoting low-carbon education, such as low-carbon knowledge competitions and themed speeches on low-carbon living, allowing students to enhance their low-carbon awareness through practice. As the backbone of society in the future, university students' behaviors and concepts have a broad influence. Once they possess a strong low-carbon awareness, they will actively practice low-carbon lifestyles in their daily lives, such as reducing the use of disposable items and advocating for green transportation. They will also spread the concept of low-carbon to those around them, thereby encouraging more people to participate in low-carbon actions, and promoting a steady shift towards sustainable development for society as a whole.

4.3 Cluster Analysis

This study's scale consisted of 33 items, through coding the scale items (see Appendix) and categorization (Table 3), it facilitated the clustering analysis of the respondents' survey data. Based on the results of the clustering analysis, the 101 respondents in this survey can be roughly divided into three categories (Table 4 and 5).

Table .3: Item Classification Table

Item Category	Item Coding
Respondents' personal views	X_1
	X_2
	X_3
	X_4
	X_5
	X_{30}
	X_{31}
	X_{32}
	X_{33}
Living habits	X_6
	X_7
	X_8
Around interviewee	X_9
	X_{10}
What other people think	X_{16}
	X_{17}

Campus environment	X_{11}
	X_{12}
	X_{13}
	X_{14}
Measures taken by the school	X_{15}
	X_{18}
	X_{19}
	X_{20}
	X_{21}
	X_{22}
	X_{23}
	X_{24}
	X_{25}
	X_{26}
	X_{27}
	X_{28}
	X_{29}

Table .5: Numbers of Respondents By Group

Cluster	1	22
	2	77
	3	2
	Effective	101
	Deficiency	0

(1) The first group: This group has a higher frequency of air conditioner use and occasionally exhibits phenomena such as leaving lights on in empty classrooms and multimedia equipment running. The daily behavior habits of this group reflect a lack of low-carbon awareness, and the environmental awareness of their peers is also relatively weak.

(2) The second group: This group has limited knowledge about low-carbon energy-saving facilities and equipment, and they witness situations where classrooms are empty but lights or multimedia equipment remain on. Additionally, this group expresses dissatisfaction with the overall campus environment and the measures taken by the school in waste sorting, environmental facilities construction, and environmental publicity.

(3) The third group: This group is relatively small in the sample and does not form significant representation, therefore, this study does not conduct detailed analysis on it.

V. CONCLUSIONS

Based on the survey and analysis results of this study, the following improvement suggestions are proposed for the current issues of insufficient low-carbon awareness and weak environmental protection facilities in the construction of green campuses.

Improve low-carbon environmental protection facilities: Strengthen the construction of low-carbon infrastructure on campus, including the introduction of clean energy sources such as solar and wind power, upgrade intelligent power systems, optimize campus lighting equipment, reduce energy waste, and thereby enhance the resource utilization and environmental friendliness of the campus.

Integrate low-carbon education content: Increase low-carbon education content in the curriculum system, offer courses related to low-carbon environmental protection, or permeate low-carbon concepts into relevant subjects, to enhance students' awareness and emphasis on low-carbon development, and strengthen their environmental awareness.

Actively organize low-carbon activities: Encourage students to actively participate in low-carbon practical activities through the organization of low-carbon knowledge competitions, theme speeches, lectures, and exhibitions, allowing students to experience and practice low-carbon concepts in real activities, and enhance their consciousness of low-carbon behavior.

Strengthen campus publicity: Use campus newspapers, campus networks, and broadcasting as media to widely promote low-carbon lifestyles, create a public opinion atmosphere for a green campus, and make low-carbon awareness deeply rooted in the hearts of teachers and students, promoting the spread of environmental culture.

Cultivate students to develop good habits: Encourage students to start with daily small things such as saving water and electricity, waste sorting, and green travel, gradually develop a low-carbon and environmentally friendly lifestyle, and influence others through their own actions, jointly promoting the green transformation of the campus.

Table .4 :Cluster Analysis of Respondents

Item number	Cluster			Item number	Cluster		
	1	2	3		1	2	3
X_1	Agree	Normal	Couldn't agree more	X_{18}	Couldn't agree more	Normal	Normal
X_2	Couldn't agree more	Agree	Not agree and quit	X_{19}	Couldn't agree more	Agree	Agree
X_3	Agree	Normal	Normal	X_{20}	Couldn't agree more	Normal	Not agree and quit
X_4	Agree	Normal	Normal	X_{21}	Couldn't agree more	Normal	Couldn't agree more
X_5	Agree	Agree	Normal	X_{22}	Couldn't agree more	Agree	Agree
X_6	Agree	Normal	Normal	X_{23}	Couldn't agree more	Normal	Agree
X7	Couldn't agree more	Agree	Not agree and quit	X24	Couldn't agree more	Normal	Normal
X8	Agree	Agree	Couldn't agree more	X25	Couldn't agree more	Agree	Normal
X9	Normal	Normal	Agree	X26	Couldn't agree more	Normal	Couldn't agree more
X10	Normal	Normal	Agree	X27	Couldn't agree more	Agree	Couldn't agree more
X11	Agree	Normal	Couldn't agree more	X28	Couldn't agree more	Agree	Couldn't agree more
X12	Agree	Normal	Couldn't agree more	X29	Couldn't agree more	Agree	Normal
X13	Couldn't agree more	Agree	Agree	X30	Couldn't agree more	Agree	Couldn't agree more
X14	Couldn't agree more	Agree	Agree	X31	Couldn't agree more	Agree	Agree
X15	Agree	Normal	Agree	X32	Couldn't agree more	Agree	Normal
X16	Agree	Normal	Strongly disagree	X33	Couldn't agree more	Agree	Agree
X17	Couldn't agree more	Normal	Normal				

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APPENDIX

Item	Number	Item	Number
You are familiar with low carbon energy saving facilities and equipment.	X1	The school's garbage sorting and recycling work is very good.	X18
You think low carbon energy saving facilities and equipment are important for environmental protection.	X2	It is necessary for schools to offer courses related to resource planning and utilization.	X19
You are willing to pay more for low-carbon and energy-efficient facilities and equipment.	X3	The school has facilities for recycling renewable resources.	X20
In your opinion, there are many types of low-carbon energy saving facilities and equipment on the market.	X4	The school's green transportation facilities such as sidewalks, driveways and electric vehicle charging stations are well planned and maintained.	X21
You will encourage others to implement low-carbon behaviors, such as green travel, water conservation, green consumption, etc.	X5	The layout and management of green Spaces on campus, such as parks and tree planting, effectively contribute to student well-being.	X22

You often use the air conditioner all day long.	X6	The school's measures for waste separation, recycling and reducing the use of single-use products are reasonable and effective.	X23
When you see the faucet open, you turn it off.	X7	The school has implemented water-saving measures and reasonable management of water resources, such as rainwater utilization and low-flow water equipment.	X24
You often use shared bikes to travel	X8	The school attaches great importance to enhancing the knowledge and participation of teachers and students in energy management.	X25
You often see an empty classroom with bright lights	X9	The school has developed a clear long-term plan for a low carbon campus and has made good progress in implementing low carbon goals.	X26
You often find teaching equipment left on when no one is using it	X10	The school has effectively carried out education and publicity activities on energy conservation and emission reduction.	X27
There is garbage sorting on campus	X11	The school energy management system has been effective in improving energy efficiency.	X28
Clean water bodies on campus (e.g. Bihe Pond, Jisi River, etc.)	X12	The school promotes the concept of low carbon.	X29
The air quality on campus is good	X13	You agree with the campus garbage sorting activity.	X30
The campus has extensive green areas	X14	You believe that campus carbon inclusion applet should be supported.	X31
There are many environmental advocacy activities or projects on campus	X15	You support your school's plan for a zero-carbon campus.	X32
The students have a strong sense of renewable resource protection	X16	You are very supportive of integrating low carbon ideas into the curriculum.	X33
Students can put the knowledge of rational use of renewable resources into practice	X17		