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Innovative Pathways for the Development of Dual-Carbon Disciplines at the Xiong'an Campus Based on Carbon Neutrality Practices

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Abstract: In the new era, against the macro background of new productive forces, the higher education system, especially the practices of carbon-neutral talent development, is undergoing a profound supply-side structural reform. This paper conducts mixed-methods research focusing on policy orientation, case analysis, and quantitative statistics to systematically deconstruct the innovative mechanisms underlying the development of carbon neutrality disciplines. The study reveals that the innovation model for dual-carbon discipline construction in universities is centered on three key pillars: the reconstruction of a "technology-economy-policy" ternary knowledge network, the integration of innovation chains through a five-dimensional collaborative mechanism of "government-industry-academia-research-application," and the reshaping of training systems based on a "micro-major-project-based-dual-mentorship" model. Drawing on a tracking study of 37 pilot universities, the empirical results of the innovation triangle model, along with the practical challenges faced in dual-carbon discipline construction, have led to the proposal of a three-stage policy framework encompassing "institutional breakthrough-resource restructuring-ecological evolution." This framework provides significant guidance for universities in constructing dual-carbon disciplines and carbon neutrality talent development at their Xiong'an campuses. Also, this paper offers theoretical support and practical paradigms for higher education to serve the national dual-carbon strategy.

Keywords: Dual-carbon disciplines; Xiong'an campus; Industry-education integration; Carbon neutrality talent development

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1. Problem statement: Structural contradictions in higher education under carbon neutrality talent development goals

1.1. The quantitative gap between strategic demand and educational supply

In 2021, the document Opinions on Fully, Accurately, and Comprehensively Implementing the New Development Philosophy to Achieve Carbon Peaking and Carbon Neutrality explicitly proposed the establishment of a talent system for carbon peaking and carbon neutrality [1]. Subsequently, the Ministry of Education launched a special initiative for carbon neutrality science and technology innovation and issued the Science and Technology Support Plan for Carbon Peaking and Carbon Neutrality (2022–2030) [2]. According to predictions by the International Energy Agency (IEA), by 2060, the global talent gap in carbon neutrality will reach 40 million people, with China accounting for over 35% of this demand. However, there is a significant mismatch in the current development of dual-carbon-related majors in Chinese universities (**Table 1**). The deep-rooted contradictions are reflected in the following three aspects.

Table 1. Analysis of talent supply and demand structure in the dual-carbon field in 2023 (Unit: Ten thousand people)

Talent category	Market demand	University supply	Shortage rate	Training cycle
Carbon Accountant	58.7	9.2	84.3%	3-5 years
Carbon Asset Manager	42.3	5.1	88.0%	2-4 years
Carbon Capture Engineer	27.6	3.8	86.2%	5-7 years
Carbon Trading Analyst	34.9	2.4	93.1%	2-3 years

(1) Fragmented Knowledge Supply: In the traditional disciplinary catalog, secondary disciplines directly related to dual carbon account for only 3.7%, and the development of interdisciplinary courses remains insufficient. Among the courses offered by the first batch of 37 carbon neutrality colleges, interdisciplinary courses make up less than 15%, and only 32% of energy-related majors include content on carbon management.

(2) Breaks in the Innovation Chain: The patent conversion rate for dual-carbon innovations in universities (7.2%) is significantly lower than the average for strategic emerging industries (18.6%). For example, the conversion rate reaches 19.8% in new energy vehicle manufacturing and 24.3% in the photovoltaic industry, highlighting the "valley of death" between laboratory research and production lines.

(3) Lagging Evaluation System: In the current assessment indicators, only 12% involve evaluations of social contribution, making it difficult to reflect the true value of dual-carbon talents.

1.2. The urgency of reform from an international comparative perspective

In comparison with major global economies, the UK's "2050 Net Zero Emission Strategy" has established a qualification certification system covering hundreds of professions, and Germany's dual education system has already incorporated carbon management into mandatory modules for engineering majors. In contrast, China's universities face the following challenges:

(1) The degree of interdisciplinary integration in course systems is only 43% of similar programs at MIT (QS Subject Evaluation data);

(2) The intensity of university-enterprise joint R&D investment (0.87%) is lower than the EU average (1.52%);

(3) The carbon literacy attainment rate among graduates is below 50%.

This gap is particularly pronounced against the backdrop of accelerating development in new, quality productive forces. It is estimated that by 2030, the supply gap in dual-carbon talent will reduce the operational efficiency of China's carbon market by 12–15 percentage points, directly impacting the progress toward achieving the 3060 goals.

2. Practical pathways: Empirical construction of the innovation triangle model

Driven by both carbon neutrality talent development goals and new quality productive forces, the development of dual-carbon disciplines in universities must break through traditional disciplinary barriers and construct an innovation triangle model that integrates "knowledge system reconstruction–training mechanism evolution–evaluation system reengineering." Based on empirical data from 37 universities that have explored dual-carbon discipline development (2021–2023), combined with multiple regression analysis and case studies, this paper reveals the core elements and operational mechanisms of the model.

2.1. Knowledge system reconstruction: Building a ternary knowledge network

The traditional disciplinary system struggles to address the multi-scale complexity of carbon neutrality talent development goals. Research shows that 78% of courses in the 37 sample universities are still offered within a single department (**Table 2**), while the enterprise demand gap for "technology-economy-policy" composite talents stands at 86%. To address this, reconstructing the knowledge system requires focusing on the following breakthrough points:

Table 2. Comparison of course structures between traditional engineering schools and new interdisciplinary colleges

Indicator	Traditional engineering schools (n = 12)	New interdisciplinary colleges (n = 25)
Proportion of Interdisciplinary Courses	11.2% ± 3.4%	37.8% ± 5.1%***
Enterprise Participation in Course Development Rate	23.6% ± 7.2%	66.9% ± 8.3%***
Patent Conversion Rate	6.7% ± 2.1%	18.4% ± 4.5%***

Note: *** indicates $P < 0.001$.

(1) Modular course cluster design

Core Module (60% of credits): Covers essential courses such as energy systems engineering and carbon metrology, utilizing a blended teaching model of "theory + virtual simulation."

Interdisciplinary Module (40% of credits): Develops cutting-edge courses like "digital twin + carbon management" and "AI + power grid dispatching," co-taught by university and industry dual mentors.

(2) Innovation in virtual-physical integrated teaching environments

The Energy Internet Research Institute at Tsinghua University has integrated real-time data systems from China's national carbon market. An emissions allocation algorithm developed by a student team was adopted by the Hubei Carbon Exchange Center, increasing regional carbon market liquidity by 9.3%. This case demonstrates that deep coupling between teaching scenarios and industrial practice can enhance knowledge conversion efficiency by 3 to 5 times.

2.2. Evolution of training mechanisms: Building a five-dimensional synergy ecosystem

The cultivation of carbon peak and carbon neutrality talent in higher education institutions must overcome the dilemma of "working behind closed doors." By establishing a collaborative mechanism involving "government, industry, academia, research, and application," deep integration of innovation and education chains can be achieved. This will accelerate the development of the "C+N" series of carbon-related disciplines and majors, promote general education courses on carbon peak and carbon neutrality, and cultivate carbon management professionals tailored to industry needs [3]. Regions should integrate educational resources, as exemplified by the European University Alliance's establishment of a green and low-carbon education cooperation platform [4].

(1) Reverse Innovation Chain Traction Model

The Joint Research Center for Clean Energy Technology, co-established by Shanghai Jiao Tong University and CATL (Contemporary Amperex Technology Co. Limited) adopts a reverse R&D pathway of "market demand → technological breakthrough → theoretical innovation." Through multi-party collaboration, the carbon footprint accounting rules for power batteries led by CATL were incorporated into the UN ECE standard framework. This achievement enabled Chinese chain-leader enterprises to reconstruct global green trade rules through "standard export + data rights confirmation" [5].

(2) Implementation of the Talent Revolving Door System

Beijing Institute of Technology piloted a "dual-appointed professor" mechanism, requiring senior engineers from energy companies to participate in teaching while university professors engage in corporate practice. The jointly developed carbon verification courses increased the carbon accounting competency rate of graduates from 37% to 89%, with 91% of graduates entering the dual-carbon field (compared to 58% under the traditional model).

2.3. Reengineering the evaluation system: A three-dimensional value creation model

The current evaluation system suffers from the chronic issue of "prioritizing publications over substantive contributions." The Outline of the Plan for Building a Strong Education Nation (2024–2035) emphasizes the need to improve a monitoring and evaluation system guided by quality, distinctiveness, and impact [6]. Establishing a diversified evaluation framework that highlights quality and contributions can effectively incentivize substantive discipline development [7–10]. Research reveals that only 12% of the assessment indicators among the 37 sample universities in this study involve societal impact. To address this, a three-dimensional "process-capability-contribution" evaluation system should be constructed (**Table 3**).

Table 3. Quantitative analysis of the effectiveness of evaluation system reforms (n = 1276)

Dimension	Traditional model means	Three-dimensional evaluation means	Improvement	T-value	Significance
Knowledge Integration Ability	68.3	79.2	16.0%	4.32	***
Complex Problem Solving	55.1	83.7	51.9%	6.81	***
Social Contribution Value	21.5	66.3	208.4%	9.14	***

Note: *** indicates $P < 0.001$.

(1) Breakthrough in the credit bank system

A carbon neutrality micro-major certification system has been established, allowing students to accumulate credits by participating in projects such as corporate carbon verification and community low-carbon transformation. This enhances students' employability and strengthens their competitive advantage in the job market.

(2) Educational transformation of carbon sink value

An innovative credit recognition mechanism has been introduced, converting industrial work completed by students into academic credits. For instance, certified CO_2 equivalent carbon sinks generated from afforestation projects are proportionally converted into innovation credits. Within the transformation chain of "ecological value → educational value → economic value," this approach provides a new paradigm for the social service function of higher education.

3. Policy recommendations: Institutional breakthroughs and ecological reconstruction

Based on the empirical results of the innovation triangle model and the practical challenges faced in dual-carbon discipline construction, and considering the ongoing development of Xiong'an campuses by many universities, this study proposes a three-stage policy framework of "institutional breakthrough-resource reconstruction-ecological evolution." This framework guides the development of dual-carbon disciplines in future university campuses within new cities. It also explores how to promote the deep integration of higher education systems with new, quality productive forces.

3.1. Institutional innovation: Top-level design to break disciplinary barriers

(1) Establishing carbon neutrality disciplines

The current Catalog of Disciplines for Degree Conferral and Talent Cultivation (2022 Edition) contains fewer than 4% of sub-disciplines directly related to carbon peak and carbon neutrality, which is insufficient to meet the demand for cultivating interdisciplinary talent. To advance the development of dual-carbon disciplines, interdisciplinary integration should serve as the key approach [11–13]. Two recommendations are proposed: First, a new primary discipline titled "Carbon Science and Engineering" could be established under either interdisciplinary studies or the engineering category, with sub-disciplines such as Carbon Management Engineering and Climate Systems Engineering. Second, a pilot "dual-degree mutual recognition" program could be introduced, modeled after MIT's "Climate System Science" initiative, allowing students to freely combine majors and minors across three disciplinary clusters: energy, environment, and economics.

(2) Building a dynamic major adjustment mechanism

Curriculum development provides essential infrastructure for disciplinary advancement, with its design directly responsive to labor market needs. Currently, China's undergraduate programs related to low-carbon development are primarily concentrated in Environmental Engineering, Environmental Science and Engineering, New Energy Science and Engineering, Energy and Environmental Systems Engineering, Energy Economics, Resource and Environmental Economics, Public Administration, and related fields [14]. As of August 2022, only 21 dual-carbon-related undergraduate programs had been established nationwide, with 2,223 program offerings [15]—far below the market demand for national development. Establishing a dynamic program adjustment mechanism would facilitate timely alignment with industrial needs, particularly for disciplines like dual-carbon that exhibit strong market-oriented characteristics, where prompt adaptation is crucial [16]. Two recommendations are proposed: First, a three-tier program evaluation system involving the Ministry of Education, industry alliances, and universities should be established, with an annual release of the White Paper on Dual-Carbon Discipline Development. Second, a "filing system" for program establishment should be implemented in cutting-edge fields such as Energy Storage Science and Engineering and Carbon Finance to shorten approval cycles.

3.2. Resource Reconstruction: A Multi-Sector Collaborative Support System

(1) Precision fiscal support

Funding is crucial for discipline development. In advancing dual-carbon discipline construction, two recommendations are proposed: First, establish a "National Dual-Carbon Education Development Fund," adopting a "base funding + performance-based rewards" model. Second, provide joint incentives for university-enterprise laboratories, including "tax deductions + equipment depreciation benefits," such as increasing R&D expense deduction ratios to 120%.

(2) Co-building and sharing data platforms

Platform construction is a key driver of discipline development. It is recommended to build a national "Dual-Carbon Industry-Education Integration Cloud Platform," integrating real-world enterprise projects, a national carbon market training system, and virtual simulation resources.

3.3. Ecological evolution: A value loop connecting education, industry, and society

Construct an "education-science-industry" innovation community. Universities should deeply participate in the national carbon market construction, undertaking 5% of MRV (Monitoring, Reporting, and Verification) functions, and incorporate carbon emission reduction contributions into discipline evaluations. Establish a carbon-inclusive mechanism for technology transfer, incorporating technical emission reductions into university assessment systems.

4. Conclusions

This study constructs an "innovation triangle model" to propose innovative pathways for developing dual-carbon disciplines in universities during the establishment of the Xiong'an campuses. Through dynamic adjustments to the discipline directory and decentralized professional settings at the institutional level, collaborative investments in fiscal resources, data, and platforms at the resource level, and mechanisms for transforming carbon value education at the ecological level, it systematically addresses structural contradictions in dual-carbon discipline construction.

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References

[1] The State Council of the People's Republic of China, 2021, Opinions of the Central Committee of the Communist Party of China and the State Council on Fully, Accurately, and Comprehensively Implementing the New Development Philosophy to Achieve Carbon Peaking and Carbon Neutrality, visited on October 26, 2024, https://www.gov.cn/zhengce/2021-10/24/content_5644613.htm

[2] Ministry of Science and Technology, National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Ecology and Environment, Ministry of Housing and Urban-Rural Development, Ministry of Transport, Chinese Academy of Sciences, Chinese Academy of Engineering, National Energy Administration, 2022, Implementation Plan for Science and Technology to Support Carbon Peak and Carbon Neutrality (2022–2030): Document No. 157 (2022) of MOST, visited on December 26, 2024, https://www.gov.cn/zhengce/zhengceku/2022-08/18/content_5705865.htm

[3] Li R, Dong C, 2024, Developing Talent for Carbon Peak and Carbon Neutrality: Strategies Under the "Dual-Carbon" Goals. China Petroleum Enterprise, 2024(10): 117–120.

[4] Xue Z, Tan X, He P, 2024, Talent Cultivation and Recruitment Strategies for Carbon Peak and Carbon Neutrality in the European Union and Their Implications. China Talent, 2024(11): 58–59.

[5] Carbon Peaking and Carbon Neutrality Working Group of Alliance of Industrial Internet and the Green Development Committee of Internet Society of China, 2025, Blue Book on Carbon Peak and Carbon Neutrality (2025). Internet Society of China, visited on March 25, 2025, https://www.isc.org.cn/profile/2025/03/21/2ba4d55a-440c-422e-a0df-85e35c61d757.pdf

[6] The State Council of the People's Republic of China, 2024, Outline for Building a Leading Education Nation (2024–2035), visited on January 19, 2025, https://www.gov.cn/zhengce/202501/content_6999913.htm

[7] Song J, 2021, Exploring and Practicing a Research Evaluation System Based on Disciplinary Characteristics and Quality Contributions: A Case Study of Communication University of China. China University Science & Technology, 2021(S1): 49–51.

[8] Qian X, Peng Y, Sun J, 2025, Innovative Talent Cultivation and Evaluation Model for the "Dual-Carbon" Strategy: A Case Study of the School of Mechanical Engineering at Yanshan University. Innovation and Entrepreneurship Theory Research and Practice, 8(5): 127–130 + 144.

[9] Wang Z, 2024, Reflection and Improvement of University Discipline Evaluation Mechanism from the Perspective of Dual-Carbon Talent Cultivation. Jiangsu Higher Education, 2024(2): 52–59.

[10] Zhang Y, 2019, What Kind of Discipline Evaluation Does "Double First-Class" Construction Need: Reflections Based on Meta-Evaluation of Discipline Assessment. Tsinghua Journal of Education, 40(5): 11–18.

[11] Cui Y, Li J, Zhang S, 2022, Interdisciplinary Discipline Construction: Connotation Analysis, Implementation Dilemmas and Promotion Strategies. China Higher Education Research, 2022(4): 16–22.

[12] Li Z, Jing H, Zhou T, Liu B, 2022, Exploration of Innovative Talent Cultivation Paths in Carbon Neutrality Field Under the "Dual-Carbon" Vision. Future and Development, 46(7): 83–86.

[13] Wang Q, Li P, Zhou J, et al., 2025, Interdisciplinary Approach Promotes High-Level Innovative Talent Cultivation: A Case Study of Tsinghua University's Carbon Neutrality Capability Enhancement Program. Academic Degrees & Graduate Education, 2025(03): 32–38.

[14] Huang Z, Jia M, Liu H, 2021, Exploration of Establishing "Low-Carbon Science and Management" Programs in Universities Under Dual-Carbon Goals. New Liberal Arts Education Research, 2021(4): 60–73 + 142–143.

[15] Wang J, Zhao K, 2024, Low-Carbon Interdisciplinary Construction Under the "3060" Strategy: Status, Experiences, and Recommendations. Review of Higher Education, 2024(2): 9–16.

[16] Li K, Sun F, Chen L, 2024, Logical Analysis and Countermeasure Research on the Establishment of Dual-Carbon Management Programs. Jiangsu Commercial Forum, 2024(10): 131–137.