Zero-carbon micro-furniture: A low-carbon emotional solution for architectural micro-spaces

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Abstract: With the development of the global low-carbon economy and the increasing demand for micro-spaces in buildings, the construction industry is facing the challenge of achieving dual goals of low-carbonization and emotionalization within limited spaces. This paper proposes the concept of "zero-carbon micro-furniture", which is defined as a new type of building accessory product that uses bio-based zero-carbon boards as the core material, adopts low-carbon processes throughout its entire life cycle, adapts to the scale of micro-spaces in buildings, and combines both low-carbon attributes and emotional value. From the interdisciplinary perspective of architectural environment and behavioral psychology, this paper analyzes the market demand and competitive advantages of zero-carbon micro-furniture. By combining the practical case of the Tongjie Zero-Carbon Magic Box Co-creation Workshop and comparing the development trends of similar products globally, it explores its application path and development strategy in micro-spaces, providing a new solution for the low-carbon transformation of the construction and furniture industries.

Keywords: Zero-carbon micro-furniture; Architectural micro-space; Bio-based materials; Emotional value; low-carbon building

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1 Introduction

1.1 Research Background

In the context of global climate change, low-carbon architecture has emerged as a pivotal trend in the construction industry. According to the United Nations Environment Programme's 2025 report, the construction sector accounts for approximately 34% of global greenhouse gas emissions[1], with indoor building-related products contributing over 15% of carbon emissions. Concurrently, as urbanization accelerates, per capita living space in cities worldwide continues to shrink annually, driving growing functional demands for

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micro-space solutions—including compact apartments, tabletop spaces, and corner areas in public zones.

Traditional architectural furnishings often merely satisfy functional requirements, presenting challenges such as high carbon footprints, poor spatial adaptability, and emotional voids. Achieving an organic integration of low-carbon sustainability and emotional resonance within architectural microspaces has become a critical issue demanding immediate resolution in the construction industry. In response, this study introduces the concept of "Zero-Carbon Micro-Furniture," aiming to provide low-carbon emotional solutions for architectural microspaces.

1.2 Research Objective and Significance

From the perspective of architectural environmental science, this study defines "zero-carbon micro-furniture" as a novel category of architectural accessories, analyzes its compatibility and application value in micro-architectural spaces, and examines practical cases from the Tongjiao Zero-Carbon Magic Box Co-Creation Workshop. By comparing global trends of similar products, it proposes development pathways and strategies to provide theoretical support and practical guidance for the low-carbon transformation of the construction industry.

2 Definition and Architectural Compatibility Characteristics of Zero-Carbon Micro-Furniture

2.1 Definitions

Zero-carbon micro-furniture refers to innovative architectural accessories that utilize bio-based zero-carbon panels as core materials, employ low-carbon production processes throughout their entire lifecycle, are designed for micro-scale architectural spaces, and combine environmental sustainability with emotional value.

2.2 Architectural Adaptability Characteristics

2.2.1 Low-carbon characteristics throughout the entire life cycle

From the perspective of the entire life cycle of architectural environments, zero-carbon micro-furniture employs negative-carbon materials such as bio-based zero-carbon panels, resulting in significantly lower carbon emissions throughout the entire process of production, transportation, use, and recycling compared to traditional building furniture. Compared to conventional wooden furniture, zero-carbon micro-furniture can achieve a 50%-70% reduction in carbon footprint, meeting the carbon emission control requirements of low-carbon buildings.

2.2.2 Adaptability of Architectural Microspaces

Based on optimized design of architectural spatial scales, zero-carbon micro-furniture features compact dimensions and flexible

modular assembly, making it suitable for micro-space scenarios such as small residential units, office workspaces, and corner areas of public buildings. In the optimization of urban small-scale living spaces, functional compatibility of micro-scale furniture is widely recognized as a core variable influencing residential experience.

2.2.3 Emotional Interactivity of Architectural Environment

From the perspective of architectural environmental psychology, zero-carbon micro-furniture provides emotional value to architectural micro-spaces through material textures, color coordination, and spatial design, such as creating natural atmospheres, alleviating spatial oppression, and enhancing user well-being. Studies have shown that architectural accessories with emotional interactivity can increase spatial satisfaction by 47% [4].

3 Market Demand Analysis for Zero-Carbon Micro-Furniture

3.1 Policy Environment

With the advancement of China's dual-carbon policies and green building standards, the demand for low-carbon supporting products in the construction industry continues to grow. The Green Building Evaluation Standard (GB/T 50378-2019) explicitly requires green buildings to meet higher standards in material conservation and resource utilization. Zero-carbon micro-furniture fully complies with the evaluation criteria for green buildings.

3.2 Building Market Demand

3.2.1 Supporting Requirements for Low-Carbon Buildings

With the increasing proportion of green buildings year by year, the market demand for low-carbon building supporting products is growing rapidly. According to data from the China Building Energy Efficiency Association, the market size of China's green building supporting products is expected to reach 800-900 billion yuan by 2025, with an annual growth rate of 18%-20% [2].

3.2.2 Functional Requirements for Architectural Microspaces

With the reduction of per capita living space in urban areas, the functional demands of architectural microspaces have become increasingly diverse. Zero-carbon micro-furniture, through modular design and flexible assembly, can meet the varied functional requirements of architectural microspaces, such as storage, office use, and leisure activities.

3.2.3 Emotional Needs of Built Environment

From the perspective of architectural environmental psychology, users' emotional demands for architectural spaces are increasingly prominent. Zero-carbon micro-furniture enhances the emotional experience of architectural spaces by delivering emotional value, thereby

fulfilling users' psychological needs. A 2025 study by the Institute of Economics at the Chinese Academy of Social Sciences indicates that consumers are increasingly willing to pay for products and services that evoke positive emotional experiences such as relaxation, happiness, a sense of being valued, and belonging. The core driver behind the growth of the emotional value industry lies in the widespread emotional needs gap in modern society and the technological advancements that have lowered the barriers to providing such emotional value [3].

3.3 Market Size Forecast

According to data from market research institutions, it is estimated that by 2030, the market size of China's zero-carbon micro-furniture will reach over 120 billion yuan, with an annual growth rate maintained at 18%-20%, becoming a significant growth pole in the building accessories market [2].

4 Global Product Comparison and Competitive Advantages of Zero-Carbon Micro-Furniture

4.1 Global Development Trends of Similar Products

4.1.1 Europe: Integration of Sustainable Design and Sensory Therapy

At the 2025 Milan International Furniture Fair, Knoll unveiled the Perron Pillo sofa, which creates a therapeutic sanctuary through its seemingly casual arrangement of oversized cushions. Each soft pad independently supports body contours, providing lounge-level comfort whether sitting, lying down, or leaning back. Its fluffy silhouette and cloud-like texture shatters the stereotype of sofas being merely for formal sitting, awakening sensory surprises in relaxed postures and elevating daily relaxation into an immersive wellness experience. Edra, a leading brand in cushion furniture, continues to enhance the comfort of its classic products by introducing innovative cushion technologies and materials that amplify therapeutic properties [7]. While these products prioritize emotional value creation, there remains room for improvement in low-carbon material applications and lifecycle sustainability practices.

4.1.2 Japan: Equal Emphasis on Ergonomics and Emotional Care

The ergonomic child sofa with spinal support available in the Japanese market features soft cotton-linen fabrics for skin-friendly comfort, high-density foam padding for lasting support, and ergonomic design to protect children's spinal health while emphasizing aesthetic appeal and style compatibility. These products excel at combining functional benefits with emotional value, though there remains room for improvement in utilizing low-carbon materials and implementing low-carbon manufacturing processes throughout their entire lifecycle.

4.1.3 China: Zero-Carbon Technology and Emotional Resonance Innovation

Yunfeng Moganshan's "Unseen" series of zero-carbon panels achieves emotional resonance through zero-carbon technology, integrating Eastern aesthetics into home environments. The plant-derived fragrance family's new tea-scented panels endow the materials with natural therapeutic properties. This product line transcends traditional panel limitations by combining environmental sustainability, aesthetic appeal, and practical functionality into a unified solution. However, further improvements are needed in architectural micro-space compatibility and modular design [8].

4.2 Competitive Advantages of Zero-Carbon Micro-Furniture

4.2.1 Product Advantages

Zero-carbon micro-furniture demonstrates significant competitive advantages in the construction industry. Compared with similar global products, its strengths are primarily reflected in the following aspects:

Comparison dimension	Zero-carbon micro-furniture	European Therapeutic Furniture	Japanese Ergonomic Furniture	China zero-carbon panel products
Low-carbon attribute	Reduce carbon footprint by 50%—70% across the entire life cycle	Insufficient application of low-carbon materials	Low-carbon processes require further enhancement	Advanced application of zero-carbon technologies
space adaptability	Modular Design for Micro-Space Adaptation in Buildings	Large size with poor spatial adaptability	Fixed size with limited spatial adaptability	板材 products exhibit insufficient spatial adaptability
Emotional Interactivity	Deliver emotional value and enhance the spatial experience	Emphasizes sensory healing but lacks architectural spatial adaptability	Emphasizes the integration of functional and emotional value, but lacks low-carbon attributes	Emphasizes natural healing but lacks emotional interactivity
sustainability	Biological-based materials are recyclable.	Some components utilize sustainable materials, but low-carbon processes throughout the entire life cycle are insufficient.	Primarily using traditional materials, resulting in severe environmental pollution	Zero-carbon technologies are being applied, but the use of sustainable materials remains insufficient.

4.2.2 Technical Advantages

Zero-carbon micro-furniture utilizes innovative building materials such as bio-based zero-carbon panels, demonstrating advanced technological sophistication and innovation. These panels are constructed from non-food/non-wood biomass sources like bamboo and wheat straw, blended with functional waste materials including coffee grounds, wine lees, and

peppermint extracts. Through processes including drying, sizing, lamination, and hot pressing, they form porous composite panels [5] that offer advantages such as low carbon footprint, durability, environmental sustainability, and cost-effectiveness. Compared to traditional particleboard, these panels surpass conventional materials in critical performance metrics including internal bonding strength, static bending strength, elastic modulus, water absorption expansion rate, and formaldehyde emission levels, fully aligning with the construction industry' s low-carbon and eco-friendly trends.

4.2.3 Industry Standard Advantages

As the pioneer in defining the innovative category of "zero-carbon micro-furniture" as a supporting architectural product, the company is empowered to participate in establishing relevant industry standards and specifications, thereby securing leadership and influence in standard-setting within the construction sector.

5 Strategies for Enhancing the Emotional Value of Zero-Carbon Micro-Furniture

5.1 Emotional Expression of Materials and Processes

5.1.1 Natural Texture Presentation of Bio-based Materials

By leveraging the natural texture and color of bio-based zero-carbon panels, spaces can be designed to evoke a sense of closeness to nature. For instance, preserving the original grain and hues of straw allows users to experience the essence of nature through tactile engagement, effectively alleviating stress and anxiety [9]. Additionally, incorporating plant-derived fragrance technology can imbue the panels with natural scents, further enhancing users' emotional experience [8].

5.1.2 Personalized Customization of Modular Combinations

Through modular design, users can freely combine the functions and layouts of zero-carbon micro-furniture according to their needs and preferences, fulfilling personalized emotional requirements. For instance, users may replace modular components based on mood and usage scenarios to create distinct spatial atmospheres. Additionally, customized services are available, allowing users to participate in the product design process and further enhance emotional engagement with the products.

5.1.3 Emotional Engagement Throughout the Life Cycle

Engage users throughout the entire lifecycle of zero-carbon micro-furniture—from material production to product design, usage, and recycling—to strengthen their emotional connection. For instance, through hands-on activities like the Straw Zero-Carbon Magic Box Co-Creation Workshop, users can craft these eco-friendly containers themselves,

experiencing material transformation and product development firsthand, thereby enhancing emotional identification [6]. Additionally, establishing a product recycling system that involves users in the process can further elevate environmental awareness and emotional resonance. See Figures 1 and 2.

Figure 1 and Figure 2: Handmade products co-created by Straw Zero Carbon Magic Box Co-creation Workshop

5.2 Emotional Creation of Architectural Spaces

5.2.1 Shaping the Emotional Atmosphere in Micro-spaces

By aligning architectural microspaces with functional requirements and user needs, zero-carbon micro-furniture elements such as color schemes, lighting, and materials can create distinct emotional atmospheres. For instance, office workspaces utilize crisp color palettes and soft lighting to foster focused productivity environments, while leisure areas employ warm hues and plush textures to cultivate relaxing comfort zones. Additionally, smart sensing technologies can be integrated to automatically adjust spatial ambiance based on users' emotional states, significantly enhancing their experiential engagement.

5.2.2 Multisensory Emotional Interaction

Through multisensory design, users can experience the emotional value of zero-carbon micro-furniture across visual, tactile, and auditory dimensions. For instance, the Zero-Carbon Magic Box incorporates natural sound modules like flowing water and bird songs, allowing users to feel serene tranquility and relaxation during use. Bio-based materials with varying textures create distinct tactile sensations that evoke different emotional responses [9]. Additionally, virtual reality technology can be integrated to enable users to experience the emotional impact of zero-carbon micro-furniture in virtual environments, further enhancing their emotional connection.

5.2.3 Social Attributes of Emotional Connections

Through zero-carbon micro-furniture design, we foster emotional connections and social interactions among users. For instance, modular zero-carbon magic boxes allow users to combine their own units with others' , creating shared spaces that enhance interpersonal communication and engagement [6]. Additionally, themed zero-carbon micro-furniture events enable users to exchange feelings and share experiences during activities, further strengthening their sense of belonging.

5.3 Emotional Identification with Brand and Culture

5.3.1 Dissemination of Green and Low-

carbon Concepts

Through brand communication and cultural development, users are encouraged to embrace the green and low-carbon philosophy embodied by zero-carbon micro-furniture, fostering emotional resonance. For instance, events like the "Zero Carbon Magic Box Co-creation Workshop" disseminate knowledge and concepts of sustainability, allowing participants to feel their contribution to environmental protection and strengthening their emotional identification [6]. Additionally, collaborations with environmental organizations to conduct public welfare initiatives focused on green and low-carbon practices further enhance the brand's social responsibility and influence.

5.3.2 Integration of Regional Culture

In the design of zero-carbon micro-furniture, incorporating elements of regional culture allows users to experience the warmth of their hometown and the continuity of cultural heritage. For example, integrating traditional Chinese patterns and colors into the design of the zero-carbon magic box enables users to appreciate the charm of Chinese traditional culture during use, thereby enhancing their sense of emotional belonging [8]. Furthermore, zero-carbon micro-furniture products tailored to local cultural needs can be designed based on the distinctive cultural characteristics of different regions, further strengthening the brand's cultural identity and regional influence.

5.3.3 Emotional Resonance of Brand Stories

By telling brand stories, users can experience the humanistic care and emotional warmth behind zero-carbon micro-furniture. For example, narrating how the Tongjiao brand extracts value from agricultural waste to create zero-carbon micro-furniture products allows users to appreciate the brand's innovative spirit and social responsibility, fostering emotional resonance. Additionally, through brand promotional videos and documentaries, the brand's development journey and cultural philosophy can be showcased, further enhancing its emotional appeal and market competitiveness.

6 Action Plan for Promoting Straw-based Zero-carbon Micro-furniture Industry

6.1 Planning Positioning and Objectives

This initiative is developed in alignment with China's dual-carbon policy objectives, market demands for zero-carbon building solutions, and the technological maturity of bio-based materials. Through phased implementation, it aims to validate the technical feasibility, economic viability, and market acceptance of zero-carbon micro-furniture. The project provides practical support for establishing industry standards and scaling up applications of this innovative product category, ultimately delivering replicable low-carbon retrofit solutions for architectural micro-spaces.

6.2 Phased Implementation Pathway

6.2.1 Technical Validation Period

Complete the standardization of technical parameters for three core categories of zero-carbon micro-furniture products (desktop storage, space partitioning, and public seating areas); establish a product quality control system encompassing material performance, carbon emission accounting, and safety standards, and obtain national-level testing and certification; collaborate with authoritative industry institutions to draft the "Technical Guidelines for Zero-Carbon Micro-Furniture"; select 3–5 micro-space applications in different building types for pilot implementation, collect key parameters such as product compatibility, user feedback, and carbon emission data, and compile a pilot validation report.

6.2.2 Scale Promotion Phase

Establish strategic partnerships with 5-10 core entities in the construction industry chain (including architectural design institutes, real estate developers, and interior decoration contractors), incorporating zero-carbon micro-furniture into architectural design selection databases and green building retrofit solutions. Implement over 10 micro-space projects across residential, commercial, and public building sectors to develop standardized scenario-specific solution templates. Establish a recycling and reuse system for zero-carbon micro-furniture to achieve material recovery rates exceeding 95% throughout the product lifecycle.

6.2.3 Ecological Construction Phase

Achieve a market share of over 5% for zero-carbon micro-furniture in the specialized architectural micro-space segment; promote the elevation of the "Zero-Carbon Micro-Furniture Technical Standard" to an industry or group standard, and include it as a bonus criterion in local green building evaluations; collaborate with bio-based material suppliers, construction enterprises, and research institutions to establish a zero-carbon micro-furniture industry innovation alliance, fostering coordinated development across the entire supply chain.

6.3 Scenario-Based Promotion Strategy

6.3.1 Residential Building Scenarios

To address the spatial needs of compact residences under 90 ㎡ —particularly in areas like living surfaces, bay windows, and entryways [3]—we develop modular products with adjustable dimensions and customizable functions. In collaboration with real estate developers, these products are incorporated into green residential turnkey delivery standards, creating "zero-carbon model units" as demonstration projects. User feedback gathered through co-creation initiatives is then used to refine product designs.

6.3.2 Office Building Scenarios

To address micro-space requirements such as desktop storage in office areas, meeting corners, and leisure zones, we

have developed products integrating ergonomic design with emotional value. These products are incorporated into corporate ESG construction plans through collaboration, promoting low-carbon office concepts via "Zero-Carbon Office" themed salons while demonstrating their carbon reduction effects and practical utility.

6.3.3 Public Building Scenarios

To address the micro-space requirements of corner areas and waiting zones in public buildings such as libraries, museums, and shopping malls, high-strength and easy-to-maintain public rest and information display products are developed. These products are integrated into spatial upgrade and renovation plans through collaboration with public building operators, while promoting standardized applications via the "Zero-Carbon Public Space" selection campaign.

6.4 Resource Integration and Outcomes Evaluation

Establish a collaborative innovation mechanism integrating industry, academia, research institutions, and application sectors, jointly conducting core technology R&D with research institutions on bio-based material performance optimization, modular design techniques, and carbon footprint accounting methods; integrate upstream and downstream industrial chain resources to build a comprehensive collaborative system covering raw material supply, manufacturing production, and installation services; collaborate with industry associations to promote standard development and industry-wide adoption.

Establish a multidimensional evaluation system encompassing technical, economic, social, and environmental dimensions to dynamically assess key indicators such as product qualification rate, market share, user satisfaction, and cumulative carbon emission reductions. The evaluation results serve as the core basis for plan adjustments and strategy optimization.

7 Development Path of Zero-Carbon Micro-Furniture in the Construction Industry

7.1 Building Materials and Technology R&D

7.1.1 R&D of Bio-based Building Materials

Strengthen the research and development of novel building materials such as bio-based zero-carbon panels to enhance material performance and quality. For instance, develop bio-based building materials tailored for diverse construction scenarios to improve fire resistance, waterproofing, and durability, thereby meeting the technical requirements of the construction industry.

7.1.2 R&D of Low-Carbon Building Technologies

From the perspective of the entire building life cycle, develop low-carbon production,

transportation, installation, and recycling processes for zero-carbon micro-furniture. For example, adopt modular production and prefabricated installation techniques to reduce on-site construction carbon emissions; establish a recycling and reuse system for zero-carbon micro-furniture to achieve resource circular utilization.

7.1.3 Research and Development of Building Environment Adaptability

Based on architectural spatial scale and functional requirements, zero-carbon micro-furniture products tailored for diverse building scenarios are developed. For instance, zero-carbon micro-furniture products adapted for residential, office, and public buildings are designed to meet the varied functional demands of architectural micro-spaces.

7.2 Market Promotion in the Construction Industry

7.2.1 Brand Building in the Construction Industry

By participating in the formulation of construction industry standards, publishing industry papers, and attending construction industry exhibitions, we aim to establish the brand image of zero-carbon micro-furniture in the construction sector and enhance its brand awareness and reputation. For example, in collaboration with authoritative institutions such as the China Academy of Building Research, we organize technical seminars on zero-carbon micro-furniture to promote its concepts and technologies.

7.2.2 Building Channel Expansion

Strengthen collaboration with B-end clients such as architectural design institutes, real estate developers, and interior decoration enterprises to expand sales channels for zero-carbon micro-furniture in the construction industry. For instance, partner with architectural design institutes to incorporate zero-carbon micro-furniture into architectural design schemes, and collaborate with real estate developers to integrate it as a complementary product for green buildings.

7.2.3 Innovative Marketing in Architectural Scenarios

Innovative marketing approaches such as architectural scenario-based experiential marketing and case promotion in the construction industry are employed to enhance awareness and acceptance of zero-carbon micro-furniture within the sector. For instance, zero-carbon micro-furniture experience zones are established in green building demonstration projects, enabling industry professionals to personally experience the advantages of zero-carbon micro-furniture.

7.3 Industrial Cooperation in the Construction Sector

Strengthen collaboration with all stakeholders in the industrial chain—including architectural research institutions, universities, building

material suppliers, and construction enterprises—to advance the development of the zero-carbon micro-furniture industry within the construction sector. For instance, cooperate with architectural research institutions to conduct technological R&D and standard-setting for zero-carbon micro-furniture; collaborate with building material suppliers to establish a stable supply system for bio-based building materials; and work with construction enterprises to improve the installation and recycling service systems for zero-carbon micro-furniture.

8 Conclusion

Zero-carbon micro-furniture serves as a low-carbon emotional solution for architectural micro-spaces, offering innovative perspectives and directions for the low-carbon transition in the construction industry. From an architectural environmental science perspective, these products effectively reduce carbon footprints of building components through bio-based zero-carbon panels, low-carbon lifecycle processes, and space-adaptive designs. Compared to global counterparts, zero-carbon micro-furniture demonstrates distinct competitive advantages in sustainability metrics, spatial compatibility, and emotional engagement throughout product lifecycles. Emotional value enhancement occurs through material craftsmanship expressions, spatial ambiance creation, and cultural brand resonance. The Tongjiao Zero-Carbon Magic Box Co-Creation Workshop's promotion initiative highlights the vast application potential and development prospects of zero-carbon micro-furniture in architecture. By advancing material technology R&D, market promotion strategies, and industry collaborations, this sector can drive sustainable development through low-carbon transformation initiatives, contributing significantly to the construction industry's green transition.

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