Research on the Application of Green Building Design in Architecture

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Abstract: As climate change worsens, green building design has become key to achieving carbon neutrality in the construction industry. This study explores core concepts and practical innovations in green architecture, focusing on energy conservation, resource recycling, and ecological integration. Through cases like the Shanghai National Exhibition Center and Dubai Sustainable City, it demonstrates how technologies such as BIM, passive design, and renewables can reduce emissions by over 40%. The paper calls for enhanced technical standards and deeper collaboration to accelerate sustainable urban transformation.

Keywords: green building; low carbon; lifecycle; BIM; sustainability

1. Introduction

With buildings responsible for nearly 40% of global carbon emissions (UNEP, 2023), the construction industry plays a central role in climate action. In response to China's "dual carbon" goals, green building design has emerged as a key solution — balancing environmental, economic, and social demands. This paper examines green design principles and strategies across four dimensions: theory, technology, case studies, and future pathways to support low-carbon urban development[1][5].

2. Theoretical framework and core principles of green building design

2.1 Definition and standard system of green building

Green building is a lifecycle-based approach that reduces resource use and pollution while improving livability. Key standards include China's GB/T 50378, U.S. LEED, and U.K. BREEAM, all emphasizing "four conservations and one protection." China classifies green buildings into four levels, evaluated across ten categories to guide sustainable transition.

2.2 Three core design principles

2.2.1 Lifecycle carbon control

Green buildings manage carbon across the lifecycle — from material production to operation and demolition — forming a closed-loop system. A model from Tianjin University limited design-phase carbon prediction errors to under 5%[2].

2.2.2 Passive-first, active-assisted

Design prioritizes passive strategies like orientation and ventilation, reducing energy loads by 30–50%, and enhances efficiency using renewables and smart systems.

2.2.3 Harmony with nature

Architecture is integrated with ecosystems via green roofs, vertical gardens, and biodiversity features. Singapore's Oasia Hotel improved indoor air quality by 40% through full facade greening.

3. Key technical strategies for green building design

3.1 Data-driven precision design

3.1.1 Integrated BIM and CFD simulation

BIM enables full-process design optimization. In Shanghai's National Exhibition Center, it cut air conditioning load by 35% and saved 28% in energy use. CFD modeling in Dubai Sustainable City improved cross-ventilation efficiency to 70%[4][6].

3.1.2 Climate-adaptive digital tools

Software like Ecotect and EnergyPlus customize design based on local climate data. In mixed-climate regions, southeast-facing layouts extended winter daylight by 2.3 hours and reduced summer heat gain by 18%.

3.2 Efficient integration of energy systems

3.2.1 Renewable energy systems

BIPV technology supplies up to 30% of a building's energy, while Dubai Sustainable City achieves full energy self-sufficiency. Ground-source heat pumps boost efficiency by 40%, with rising adoption in regions like Hebei and Shandong.

3.2.2 Cascade energy utilization (CCHP)

Combined cooling, heating, and power systems reuse waste heat, increasing efficiency to 85%. In a Shanghai green park, CCHP cut CO_2 emissions by 12,000 tons — equivalent to planting 67,000 trees.

3.3 Closed-loop management of resource circulation

3.3.1 Green building materials

Eco-materials like low-carbon cement and recycled concrete reduce construction waste by 30% and emissions by 25%, as shown in a Shenzhen project[3].

3.3.2 Water recycling systems

Rainwater collection and reclaimed water technologies enable over 30% alternative water use. Singapore's Gardens by the Bay meets 80% of irrigation needs this way, saving 65% in water annually.

3.4 Improvement of the health of human settlements

3.4.1 Natural lighting and ventilation

Designs using atriums and light pipes enable 90% of rooms to meet natural light and airflow standards. A Hangzhou office achieved 85% ventilation coverage, reducing indoor PM2.5 by 60%.

3.4.2 Smart indoor environment control

Sensors monitor air quality and link to HVAC systems. A zero-carbon apartment in Beijing cut energy use by 45%, with 92% resident satisfaction from its intelligent maintenance system.

4. Fourth, case study analysis: from regional practice to global experience

4.1 Domestic research

The Qianhai Huafa Snow World project in Shenzhen, led by China Construction Third Engineering Bureau, is a large-scale urban development with ongoing construction, but lacks documented green design features.

4.2 Vanke Center Green Upgrade, Shenzhen

The Vanke Center in Dameisha was transformed into a near-zero carbon community featuring BIPV panels, rainwater reuse, ecological greening, and smart controls. It achieved LEED Platinum and China's Three-Star Green Building rating. The upgraded system includes microgrids, zero-waste recycling, and biodiversity features. Post-renovation, energy savings reached 85%, with full green electricity adoption.

4.3 Zero-carbon Pavilion at Shanghai Expo

China's first zero-carbon public building, the Shanghai Expo Pavilion, integrates rooftop wind turbines, curved PV panels, and biodegradable materials. Rainwater systems achieve water self-sufficiency. A "carbon points" system and real-time tracking app engage users in energy-saving behaviors, boosting savings by 12%. Overall, operational carbon emissions were 15% lower than design estimates, with renewable systems covering 60% of energy use and passive walls cutting cooling load by 30%.

5. Challenges and development paths of green building design

5.1 Existing problems

5.1.1 Climate adaptability issues

In cold regions, airtight passive buildings can cause CO_2 buildup; in hot, humid areas, dusty PV panels lose 15% efficiency, and cleaning wastes large volumes of water[7].

5.1.2 Smart tech limitations

Over-reliance on sensors and AI drives costs above 20%, while energy savings remain marginal (8–10%). Data accuracy suffers due to incompatible subsystems.

5.1.3 Lifecycle carbon accounting gaps

Current standards undercount embodied carbon from material transport, causing up to 18% errors in project assessments.

5.2 Development countermeasures

5.2.1 Policy and market mechanisms

Offer subsidies (200–500 yuan/m²) and FAR bonuses for green buildings; establish a carbon trading market that values carbon savings.

5.2.2 Tech innovation and integration

Advance cross-disciplinary systems like building-integrated PV and storage. Use parametric tools and collaborative design to optimize performance.

5.2.3 Lifecycle management systems

Incorporate operational carbon into certifications. Deploy AI-driven platforms for predictive maintenance and energy optimization.

6. Conclusion and Prospect

Green buildings are evolving toward carbon-neutral systems, with three key trends: BIPV and energy storage turning buildings into power nodes; biomimetic design improving efficiency through nature-inspired forms; and digital twin tech enabling accurate lifecycle energy simulations. To meet 2030 targets, China must combine tech innovation, robust standards, and policy support — shifting from certification-driven to value-driven development to lead global green transformation.

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