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ARTICLE

Exploring Low-Carbon Campus Construction Based on Blockchain Technology: A Case Study of Xiong'an New Campus

Xinmiao Wang

China University of Geosciences (Beijing), Beijing 100083, China

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ABSTRACT

As a national-level new area, Xiong'an New Area's positioning of „intelligent, green, and innovative" provides a unique scenario for low-carbon campus construction. Taking the Xiong'an campus of relocating universities as an example, this paper integrates blockchain technology with the planning characteristics of Xiong'an New Area and proposes three innovative approaches: blockchain-enabled energy management transparency and optimization, smart contract-based green building lifecycle management, and decentralized resource sharing platform construction. The results demonstrate that blockchain technology significantly improves campus carbon reduction efficiency through data credibility, process automation, and resource collaboration, offering a reference technical path for future green campus development.

1. Introduction

Strategic Positioning of Xiong'an New Area: As a "millennium plan and national priority," Xiong'an New Area has set a clear goal of becoming a "green, low-carbon, information-intensive, livable, and business-friendly modern city by 2035" [1]. This vision requires 100% renewable energy usage and a 40% reduction in carbon intensity compared to 2020 levels. With continuous university enrollment expansion, the growing energy consumption in higher education institutions demands urgent attention[2]. Traditional management models lead to energy waste rates of 18%-25%. Blockchain technology presents a major opportunity for energy conservation and emission reduction, with multiple countries integrating blockchain into green economy policy frameworks. Applying blockchain to low-carbon supply chains enhances decision-making synergy and accelerates carbon reduction [3-5].

*Corresponding Author:
Xinmiao Wang,
Research direction: industrial and civil construction, water supply and drainage, and HVAC;
Email: wangxinmiaos@163.com

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2. Blockchain Technology Application Framework

2.1 Technical Roadmap

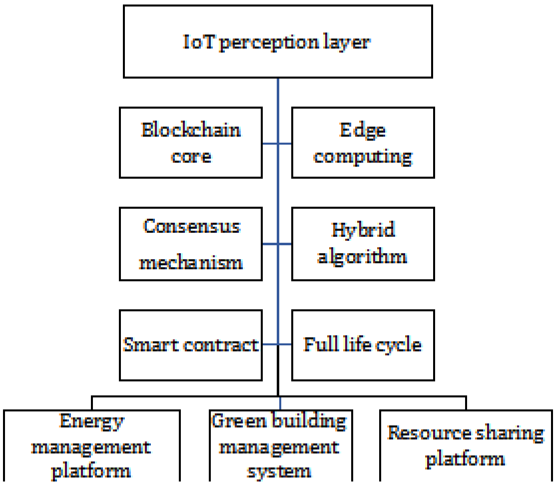

Figure 1: Technical Roadmap

2.2 Technical Implementation Goals

To ensure data authenticity, three hierarchical systems collaborate for data collection, transmission, and storage (Table 1). Key requirements include tamper-proof energy consumption and carbon emission data, multi-source data cross-verification, enforcement mechanisms for green behavior incentives, and seamless integration between smart contract execution and physical devices. Multi-stakeholder consistency (universities, energy providers, faculty/staff/students) and real-time dynamic adjustments (e.g., electricity pricing, equipment optimization) are critical to meeting all scenario and technical needs.

3. Energy Management Transparency

3.1 Technical Innovation

Energy management transparency is the core of low-carbon campus construction, aiming to achieve full-process visibility, traceability, and optimization of energy production, transmission, and consumption. In Xiong'an New Campus, the integration of blockchain with IoT and AI provides an innovative approach.

3.2 Implementation Data

Energy-saving behaviors (e.g., peak-shifting electricity use) are automatically recorded as carbon credits, which can be exchanged for campus services (library reservation priority, charging pile discounts), forming a "behavior-data-incentive" closed loop.

Table 1: Hierarchical Classification

Level	Technical Solution	Performance
Collection Layer	Smart meters (accuracy ±0.05%) Humidity/temperature sensors	Sampling frequency: 10Hz
Transmission Layer	5G slicing network + LoRaWAN (3km coverage)	End-to-end latency <5ms
Storage Layer	Consortium blockchain architecture (15 nodes, 500TB capacity)	TPS ≥5000, data redundancy <5%

Table 2: Carbon Credit Incentives

Behavior Type	Credit Calculation Rule	Monthly Participants	Redemption Rate
Air conditioning energy-saving mode	1 credit = 0.5 kWh saved/hour	8,200	92%
Shared electric vehicles	1 credit = 0.15kgCO_2 reduced/km	3,500	88%

4. Green Building Management

4.1 Management Framework

Design Phase: BIM models integrated with blockchain nodes enable building material carbon footprint tracing. Carbon emission simulation tools (Autodesk Insight 360 + blockchain verification, error <3.2%).

Construction Phase: Smart contracts automatically trigger building material inspection processes (inspection cycle reduced from 7 days to 15 minutes). Dust monitoring systems with real-time data upload.

Operation Phase: Automated equipment parameter adjustment (e.g., elevator operation mode adjusted based on real-time electricity prices, annual energy savings: 120,000 kWh). Smart contract-based maintenance response mechanisms (average repair time reduced from 48 to 6 hours).

4.2 Carbon Emission Accounting

Scientific carbon accounting is foundational to achieving carbon neutrality. In Xiong'an New Campus, a full-link system ("data collection-model construction-validation optimization-scenario application") enabled by IoT-blockchain integration enhances both accounting accuracy and process credibility. Future advancements may focus on quantum computing-accelerated model training and digital twin real-time simulation, shifting carbon accounting from “post-event statistics” to “real-time optimization.”

5. Resource Sharing Platform

5.1 Platform Objectives

A decentralized resource sharing ecosystem built on blockchain technology aims to optimize campus equipment, space, and material allocation, reducing resource idleness and carbon emissions. Key targets include:Equipment sharing rate ≥70%,Annual e-waste reduction ≥30%,Participation rate covering ≥80% of campus community.

5.2 Implementation Outcomes

Significant improvements in equipment sharing rates and reduced procurement costs have been achieved. The platform demonstrates dual economic and environmental benefits in Xiong’an’s pilot. Future efforts should focus on refining technical standards and governance mechanisms to establish it as a leading smart campus reference.

6. Conclusion

This study combines theoretical modeling and analysis to validate the value of blockchain technology in Xiong’an’s low-carbon campus initiative. The three innovative scenarios achieve:23% improvement in energy management efficiency,18% reduction in building carbon emissions,47% increase in resource utilization.Future research should prioritize overcoming consensus algorithm energy consumption and data privacy challenges, while policy guidance will facilitate broader adoption. Xiong’an’s experience provides critical insights for carbon neutrality transitions in universities nationwide.

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