



## Editorial

## Editorial for the Special Issue on Carbon-Neutrality Pathways for Building Operations

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Building operations—that is, the continual activities and processes required to manage and maintain buildings—are responsible for approximately 30% of global energy use and 26% of carbon dioxide (CO<sub>2</sub>) emissions. Technological pathways for conserving energy and reducing carbon emissions in building operations, the development of disruptive technologies in this field, and the synergy of low-carbon technologies among the building, transportation, industry, and energy sectors have become global research frontiers. Substantial reductions in operational carbon emissions are expected to transform building construction, operation, maintenance, and repair, driving revolutionary changes across the industry.

This special issue aims to promote the advancement of the carbon-neutrality concept and technologies in building operations worldwide; it covers topics such as building envelopes and materials, optimized energy system design for buildings, and flexible energy control for demand-side management. A total of six papers have been accepted after a rigorous peer-review process. The main contents and contributions of each paper are introduced below.

The article “Ecological pathway to achieve carbon neutrality in China’s building sector” proposes a comprehensive ecological development pathway toward carbon neutrality. Key strategies include managing building stock, increasing energy efficiency, promoting electrification, implementing photovoltaic energy-

storage direct-current flexibility (PEDF) buildings, decarbonizing heating systems, and advancing new rural energy systems. This study provides valuable recommendations for policymakers and insightful guidance for future research and engineering practices.

Innovations in building envelopes and materials are crucial for reducing energy demand. The review titled “Excellent insulation vacuum glazing for low-carbon buildings: Fabrication, modeling, and evaluation” systematically evaluates vacuum glazing and composite structures, detailing material selection, fabrication methods, research approaches, and performance assessments. It identifies future trends and provides directions for theoretical research and industry applications.

Optimized energy system design and equipment selection for buildings ensure precise energy supply–demand matching, thereby improving occupant comfort and achieving building energy sufficiency and efficiency. The article “Indoor thermal environment improvement based on switchable radiation/convection-combined intermittent heating: Comparison between conventional terminals and an integrated novel terminal” proposes a switchable convective–radiant heating method for floor heating and fan coils that enables a rapid thermal response and improved thermal comfort, demonstrating substantial potential for energy conservation.

Leveraging building flexibility can effectively address power fluctuations due to intermittent and uncertain renewable energy sources. The article “Optimal scheduling and on-the-fly flexible control of integrated energy systems for residential buildings considering photovoltaic prediction errors” introduces a cross-time-scale control framework to manage residential building flexibility in integrated energy systems. This framework involves solar irradiance forecasting, day-ahead energy storage scheduling, and intra-day heat pump control. The effectiveness of the method is validated through case studies.

The article “Risk-aware optimal dispatch of resource aggregators integrating NGBost-based probabilistic renewable forecasting and bi-level building flexibility engagements” presents a risk-aware dispatch strategy that integrates probabilistic renewable energy forecasts with bi-level building flexibility management. Chance-constrained programming is utilized to maintain the resource aggregator’s supply–demand balance and manage

operational risks effectively. The results demonstrate mutual benefits, including a 13% load reduction, increased profitability, and a 3% reduction in carbon emissions.

The article “Decarbonization of building operations with adaptive quantum-computing-based model predictive control” proposes an adaptive quantum approximate optimization-based model predictive control strategy for energy management in buildings with battery storage and renewable generation systems. The application of this strategy at the Cornell University

campus resulted in a 41.2% reduction in carbon emissions, highlighting significant potential for energy efficiency and decarbonization.

We sincerely thank all the authors for their valuable contributions and extend our gratitude to all the reviewers and guest editors. We also thank Dr. Shan Hu of Tsinghua University, who contributed greatly to the organization of this special issue. We hope this special issue fosters further research and engineering advancements toward building carbon neutrality.