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Editorial

The Role of AI-Driven Synergy in Achieving Net Zero Buildings

Maurizio Acciarri *

Department of Materials Science, University of Milano Bicocca, v. R. Cozzi 55, I-20125 Milano, Italy

* Corresponding author. E-mail: maurizio.acciarri@unimib.it (M.A.)

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The transition to zero-emission buildings is one of the most urgent challenges in tackling climate change. The building sector contributes about 30% of global energy-related CO_2 emissions. According to the International Energy Agency (IEA), global building area is projected to increase by 75% over the next 30 years, with 80% of this growth in emerging markets. To meet climate neutrality targets, direct emissions from buildings must fall from 3 Gt in 2020 to less than 2 Gt by 2030 and only 120 Mt by 2050 [IEA].

Artificial intelligence (AI) is emerging as a key technology in addressing this challenge. Machine learning algorithms optimize energy consumption, improve HVAC efficiency, and enhance renewable energy integration. AI-based predictive models analyze occupancy patterns, weather, and grid availability to adjust energy use dynamically. AI-enhanced smart grids and demand management systems balance real-time energy production and consumption, supporting intermittent renewables. Additionally, AI enables precision control of lighting and ventilation through automated systems, further reducing energy waste.

However, AI alone is not enough. The transition also requires material innovations and advanced building solutions. High-performance insulation, phase-change materials for thermal storage, and next-generation photovoltaics are essential for reducing energy demand. Emerging technologies such as energy-harvesting surfaces, dynamic glazing that adjusts transparency based on sunlight, and integrated storage solutions significantly enhance building efficiency. These innovations, when combined with AI-driven energy optimization, will play a decisive role in shaping the future of net zero buildings.

The IEA estimates that by 2030, all new buildings should be carbon neutral, while at least 20% of existing buildings must be retrofitted. AI can identify optimal renovation strategies, quantify energy-saving potential, and guide decision-making. However, real progress will come from the synergy between AI, physics, engineering, and material science. AI provides optimization tools, but the expertise of physicists, engineers, and material scientists is crucial for developing efficient and sustainable building solutions. Only through a multidisciplinary approach—where artificial intelligence and physical sciences work together—can we create high-performance, sustainable buildings that meet the needs of a rapidly changing world.

Beyond technology, achieving net zero buildings requires societal engagement and financial commitment. Smart cities and energy communities are playing a growing role in this transition. AI-driven energy management systems optimize decentralized generation from rooftop solar panels and small wind turbines, allowing buildings to exchange energy efficiently. Digital twins—AI-powered virtual models of buildings and infrastructure—can simulate energy flows and predict inefficiencies, improving both design and real-time operations.

Additionally, governments and financial institutions have a crucial role in accelerating this shift. Policy frameworks promoting tax incentives, energy efficiency mandates, and low-interest green financing are key to encouraging investment in sustainable building technologies. Collaboration between public and private sectors is essential to scaling these innovations. Public awareness and education programs will also be vital in driving behavioral change, encouraging individuals and businesses to adopt energy-efficient practices.

The path to a zero-emission future is not just a technological challenge but a collective responsibility—requiring coordinated action from scientists, policymakers, industry leaders, and citizens. Only through an integrated approach,

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where technological innovation, material science, and public engagement align, can we accelerate the transition to truly sustainable buildings and a decarbonized future.

[IEA] https://www.iea.org/reports/technology-and-innovation-pathways-for-zero-carbon-ready-buildings-by2030/introduction (accessed on 5 March 2025).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.