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Editorial: Intelligent systems for sustainable building: balancing IEQ with energy efficiency

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Editorial on the Research Topic
Intelligent systems for sustainable building: balancing IEQ with energy efficiency

In the wake of pressing global climate challenges and growing comprehension of occupant-centric environments, the integration of intelligent systems into the built environment has emerged as a necessary progression, rather than a technological aspiration. This Research Topic brings together an assortment of perspectives—from the rigor of structural logic and thermal dynamics to the finesse of spatial design, environmental psychology, public health, material innovation, and advanced modeling. At its core lies a shared vision: to create built environments that are not merely energy—efficient, but also profoundly sustainable. It is our great pleasure to publish this Research Topic.

The collected works exhibit this interdisciplinary convergence by providing new perspectives on the ways that daylighting interacts with human behavior, air quality interacts with algorithms, and facades morph from static shells to dynamic, kinetic and intelligent skins. In this interplay of scientific experience and technological research, we explore how built environment can both sense and serve efficiently. Building on this collective vision, the convergence of Indoor Environmental Quality (IEQ) and energy-efficiency emerges not as a trade-off, but as a symbiotic relationship that shapes human-centric design across scales—from small interior spaces to expansive urban environments.

This Research Topic features evidence-based narratives that transcend conventional boundaries to nudge the depth and width of diverse perspectives on the topic. For instance, at the building scale, the Delhi Public Works Department case study by Budde et al. demonstrates how coalescing smart ventilation and adaptive controls may substantially boost thermal comfort and occupants' productivity while whittling operational energy use. At the neighborhood and city scale, insights from the Bangladesh case by Hossain et al. reveal systemic challenges and solutions in scaling intelligent technologies for sustainable urban development. Goldstein et al. work is as intriguing in its interdisciplinary approach, which reimagines architectural design through the prism of human experience using

AutoCAD-driven teamwork, combining digital spatial modeling with psychological and social wellbeing metrics. Baraboi et al. provide vital insights into how smart 3D-printed facades, using new materials and AI-integrated design, can dynamically improve IEQ while lowering energy use. It is firmly aligned with the Research Topic's vision, which promotes adaptive, sustainable, and human-centered building systems. Collectively, these works demonstrate that the goal of sustainable built environments must not only balance comfort, health, and efficiency, but also anticipate the diverse demands of persons and communities.

Through data-rich simulations, material innovations, and AI-augmented decision systems, the articles in this Research Topic highlight that smart solutions are most savvy approaches when scaled thoughtfully—from a single room to multiple, multi-storeyed buildings and then to the whole nation or the globe. The four papers published in this Research Topic have the following brief highlights:

Budde et al. study examines how smart air purification systems in high-rise urban buildings can balance good indoor environment and energy efficiency. Using Energy Plus simulations, it evaluates how predictive control, optimized window scheduling, and HEPA filters improve HVAC performance. Results show reduced energy use, lower pollutant infiltration, and healthier indoor conditions. The work highlights the potential of IoT-driven, adaptive HVAC strategies to enhance occupant health and system efficiency—advancing the core goals of intelligent, and sustainable building design.

In alignment with the theme of balancing environmental quality and energy efficiency through intelligent systems, Hossain et al. offer a compelling study on ambient air quality in Bangladesh. Sensor data from 48 locations reveal $PM_{2.5}$ levels nearly eight times WHO limits, with over half the population exposed to "very unhealthy" PM_{10}, especially in traffic-heavy zones. Their findings highlight the urgent need for intelligent, data-driven building systems such as smart filtration, adaptive ventilation, and responsive facades; to safeguard health while supporting sustainable, energy-efficient urban growth.

Goldstein et al. researchers presents a novel computational framework designed to analyze and quantify three pragmatic spatial qualities within habitable indoor environments. Using a digital twin–inspired model, the study integrates architectural parameters and spatial configurations to generate composite experiential scores. These were applied across 20 apartment models and validated through an online crowd-sourced survey that captured human perception of these qualities. Notably, while human raters tended to assign similar scores to entire rooms, the algorithm successfully revealed subtle spatial gradients, showcasing the enhanced granularity and precision of computational analysis. The authors emphasize the need to extend this framework; so, the methodology could become instrumental in guiding architects and engineers in creating dynamic and responsive spaces that simultaneously enhance occupant wellbeing and optimize energy performance—epitomizing the balanced and intelligent design ethos promoted by this Research Topic.

Baraboi et al. review advances the topical theme by exploring smart 3D-printed facades as a fusion of design innovation and sustainability. Gaging 76 studies (2015–2025), it highlights how sensor-integrated, AI-driven facades can adapt to environmental changes—modulating light, heat, and airflow to optimize IEQ and energy use. The review connects materials like PETG/PLA to durability and circularity while addressing real-world challenges (cost, scalability, standards). It calls for lifecycle analysis, climate-resilient modeling, and IoT integration, shifting focus from aesthetics to intelligent performance—promoting adaptive, efficient, and occupant-centric built environments.

As we conclude this editorial, the richness of this collaborative journey stands as a testament to the interdisciplinary synergy driving sustainable innovation in the built environment. Across one narrative review and three pioneering research contributions, 28 dedicated authors, 9 meticulous reviewers, 4 engaged topical editors, efficient journal editorial office team and publication staff have worked together to unravel the complexities of intelligent systems in built environment, while balancing IEQ with energy-efficiency. This Research Topic bridges academic insights, and industry expertise via research rigor, representing a mosaic of perspectives from nine nations across North America, Europe, South Asia, and the Middle East. By integrating disciplines such as civil and architectural engineering, environmental science, public health, modeling, and AI, this effort exemplifies a shared commitment to human-centric, environment-friendly, energy-responsible built environments; from buildings to neighborhoods, cities, and beyond. The collective voice in this Research Topic calls not just for technological advancement, but for holistic progress that respects human comfort, climate-resilience, and social equity. Let this initiative serve as both a milestone and a call to action for continued interdisciplinary collaboration toward a sustainable, intelligent, and inclusive future.

Author contributions

NK: Writing – original draft, Writing – review & editing, Resources, Formal analysis, Project administration. AsK: Writing – review & editing, Supervision, Validation. TA: Project administration, Supervision, Writing – review & editing, Resources. AnK: Supervision, Writing – review & editing.

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AsK was employed by ArchiTech Consultants.

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