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Smart technologies in performance-based design

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Data and design have become a symbiotic relationship, driving modern architecture into an era where performance-based design is reshaping and improving outcomes for tenants, building owners, and the planet. As performance-based design becomes a standard rather than a specialty, smart technologies are emerging as a central focus in the design and operation of buildings. These tools enhance energy efficiency and occupant experience, but perhaps most importantly, they serve as critical instruments for climate adaptation and mitigation.

As the built environment contends with rising temperatures and sea level changes, more powerful and more frequent storm events, and shifting environmental patterns, smart technologies offer designers the ability to anticipate these changes and create buildings with improved climate resiliency to stand the test of time. More than just convenience, smart technologies drive design decisions that influence occupant comfort, energy performance, climate resilience, and long-term adaptability. Computational fluid dynamics (CFD), sensor-based building controls, and intelligent systems integration are three powerful tools driving the future of performance-based design.

CFD: A predictive tool for designers

Among the most transformative advancements in performance modeling is computational fluid dynamics. Once considered a specialized tool used sparingly for complex modeling, CFD has now matured into a cornerstone of performance-based design, especially for projects where thermal comfort, wind mitigation, and climate resilience are non-negotiable. CFD simulations enable architects and engineers to test a wide range of environmental scenarios before a shovel ever hits the ground, both inside and outside the building. In the context of climate resiliency, CFD can be used to model how extreme heat, shifting wind patterns, and increasing storm events might affect building performance and occupant comfort. Urban projects in flood-prone or heat-vulnerable areas can benefit immensely from CFD's ability to simulate stormwater runoff, thermal loading, and airflow

around buildings.¹ When used early in the design process, CFD becomes a predictive tool, one that allows architects not just to respond to environmental forces but to anticipate and plan for a future shaped by climate change and harsh meteorological events.

Sensor-based controls: Optimizing daily performance

Often seen in both commercial and residential spaces (new construction and retrofits), sensor-based building controls are a more recognized evolution in performance-driven design. Once reserved for high-end, new construction Class A buildings, these technologies are slowly being retrofitted into smaller commercial Class B and Class C buildings, transforming outdated assets into adaptive, intelligent environments.² Research has demonstrated that 15-25% of global energy consumption could be conserved by identifying occupancy levels and optimizing systems within a building.³ Smart sensors embedded in lighting, HVAC, and occupancy systems create responsive spaces that dynamically adjust to real-time conditions. Lighting systems can dim automatically in response to daylight levels or room occupancy, reducing energy usage while enhancing visual comfort. Similarly, peer-reviewed research⁴ shows that demand-controlled and occupant-centric HVAC systems can monitor indoor air quality, temperature, and usage patterns, and adjusting airflow and conditioning can significantly reduce energy use⁵ while maintaining thermal comfort. These small adjustments, often unseen by the occupants, generate significant energy savings over time. Sensor-based controls are also influencing user expectations.⁶ As building owners anticipate a return to hybrid workplaces, their tenants will expect buildings to work harder and smarter, maintaining comfort, reducing waste, and supporting wellness.

Coordinated systems, tangible results

Smart system integration enhances building performance by unifying lighting, HVAC, security, and other systems through a centralized software platform.⁷ Utilizing real-time data, these interconnected systems can adapt simultaneously to environmental changes, such as adjusting lighting, ventilation, and cooling loads to optimize energy use and indoor comfort. This coordinated approach not only improves efficiency but also elevates a building's resilience by enabling it to respond proactively to climate variations, air quality issues, and storm conditions. By combining and synchronizing response systems, smart integration strengthens a building's ability to operate reliably and sustainably in both routine and extraordinary circumstances.

Adapting to the redefined role

Taken together, CFD modeling, sensor-based controls, and integrated smart systems are redefining the toolkit for performance-based design. Each element plays a critical role: CFD enables climate-responsive massing and envelope design; sensors enable dynamic, user-centered environmental

control; and integrated systems ensure that every smart function contributes to a larger performance narrative. The end result is a shift in the role of the architect and designer, from creating static forms to orchestrating dynamic environments.

Continuous improvement for a changing environment

Smart technologies create environments where performance is consistently measured, refined, and optimized over time. This transition from static prediction to dynamic calibration allows buildings to evolve with their users and respond to shifting environmental challenges. In a time of climate volatility and stricter regulations, this ability to adapt continuously is crucial. Performance-based design is no longer just about a single simulation or certification; it's about ongoing accountability to key metrics: energy efficiency, occupant well-being, operational resilience, and environmental impact. Smart technologies equip buildings to not only comply with codes but to exceed expectations and play a significant role in long-term climate adaptation.

The true promise of smart technologies in performance-based design is not merely in their novelty or complexity, but in their ability to deliver better outcomes, particularly in supporting climate resilience alongside energy performance and occupant well-being. By embedding intelligence into buildings through modeling, sensors, and system integration, design teams can deliver spaces that are not only efficient and adaptive but also resilient, health-promoting, and future-ready. As the built environment faces increasing demands for sustainability, flexibility, and occupant well-being, these technologies will define the next era of design excellence.

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