Trends and Future Directions

Occupant Health & Well-Being in Green Buildings

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Expectations for high performance green buildings have been evolving over the last four decades. Green certification systems define, recognize, and demonstrate leadership in addressing building problems related to people and the environment. These systems are premised on a theory of change where making the distribution in building performance visible provides opportunities for competitive differentiation that motivates and rewards action to create better spaces, buildings, and places. To date, there are more than 200 different green building certification programs around the globe, with estimates of at least 1 million certified projects.

Although each certification scheme has different features, they all share common, core objectives: To minimize environmental impact by reducing site disturbance, energy and water use, and waste generation; and promote human health and occupant experience. Human health benefits are also targeted as an indirect benefit of the climate change mitigation goals implicit in energy reduction. But while the green building industry has a long-standing history of attention to human health (e.g., tobacco control, toxic exposures), there has been a recent shift in the prioritization of this issue relative to the others, with a new emphasis on features that explicitly promote the human experience of building occupants. Targeted aspects of that experience include health, performance, comfort, and well-being. New research, rising expectations, and emerging technologies have also motivated a shift toward operational performance measurements to validate the impact of prescriptive guidelines. The same drivers have created a glut of opportunity, which needs to be harnessed strategically to avoid prescriptions that are too complex, too expensive, and potentially redundant.

To design and optimize these strategies, we need real-world, robust, comparable evidence on the impact of indoor environmental quality (IEQ) interventions on people and organizations, and a systems-view on benefits and trade-offs across context-specific human and environmental parameters. To frame the state of knowledge

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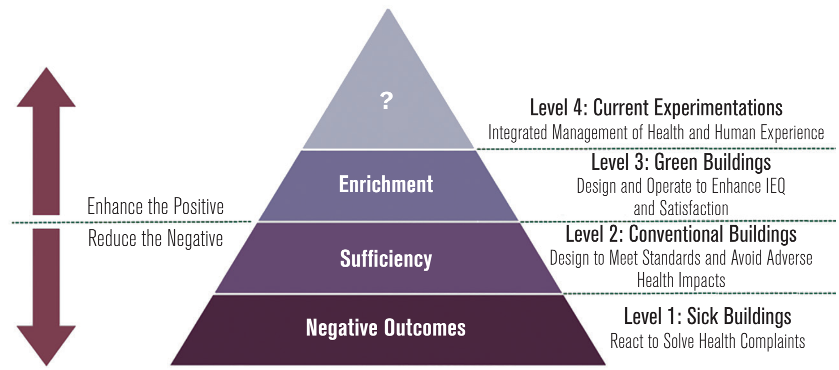
and future directions, we classify existing approaches to address human experience in buildings into three tiers. We also present recommendations for the future, which we conceive of as the fourth tier in our model (*Figure 1*).

FIGURE 1 The "health performance pyramid" illustrates the progression from reactive work to address acute health complaints (Tier 1) to rare combination of proactive, integrative efforts to provide superior occupant experience together with exceptional environmental performance (Tier 4).



Tier 1 illustrates approaches to addressing "sick buildings". This is the most conventional approach to health promotion; reactive and disconnected from other performance areas. Work on Tier 1 buildings is often triggered by reports of Sick Building Syndrome (SBS) symptoms (e.g., headache, nausea, dizziness, fatigue, irritation of throat/eye/nose, difficulty in concentration), or specific cardiovascular, respiratory, or other illnesses. An abundant body of research links many of these health outcomes to environmental exposures to physical, biological or chemical hazards such as asbestos, allergens, mold, radon, infectious agents, and particulate matter.[1]

A strong body of research also links low ventilation rates to SBS symptoms, increased sickness absenteeism and reduced productivity.[2,3] The number of buildings with elevated SBS symptoms persists, despite the longstanding evidence that energy-related cost savings due to reduced ventilation are by far exceeded by the related costs of SBS symptoms.[4] Similarly, buildings with undesirable exposures persist, often in resource-constrained scenarios. These are often experienced in the context of broader issues related to equity, access, and environmental justice. The recommendation in these cases is to focus resources on remediation.

Tier 2 buildings represent the majority of the existing conventional, commercial building stock. Tier 2 buildings aim to be designed and operated to comply with building codes and standards for the indoor environment. This level of performance intends to satisfy minimum legal requirements. Tier 2 practices include the provision of outdoor air, reduced indoor emissions, and protection against outdoor air pollution. The codes, such as ISO EN 7730, EN 15251, ASHRAE Standard 55 and ASHRAE Standard 62.1 outline "acceptable" values rather than human-centric "good" values.[5] These aim to ensure the substantial majority (typically 80% or more) of occupants do not express dissatisfaction, and that there is a margin of safety to avoid known, acute health risks.

Unfortunately, despite the significant progress in the development of building ventilation and indoor air quality standards, occupant satisfaction surveys conducted in hundreds of buildings worldwide indicate that percentage of satisfied people is significantly lower than the 80% goal.[6,7] Gaps exist in the provision of adequate ventilation and filtration, as well. For example, scientific research has shown that ventilation rates several times higher than the level specified by ASHRAE Standard 62.1 are needed to minimize SBS symptoms and improve productivity.[8]

Measurements campaigns in code-compliant buildings typically find levels of health-relevant pollutants to be below thresholds of concern on average, but with significant spatial and temporal hotspots. These have been linked to unexpected intrusion of outdoor air pollution, outdoor events such as wildfires, densely occupied conditions, activities such as cooking, cleaning, installation of a new carpet, etc.

There is now a significant body of research showing buildings can do more to support human performance and experience. Spaces with ample daylight, high ventilation rates, and superior IEQ are consistently documented to be more satisfying for occupants. Moreover, an opportunity space has been opened up by new IoT sensor technology.[9] Emerging technology has the potential to provide cost-effective measurement of IEQ conditions over finely resolved spatial and temporal scales. This allows for the detection and management of hotspots and other transient conditions.

Tier 3 includes green buildings that aspire to exceed the requirements of existing, minimum codes and standards.[10] Green certification programs provide a mechanism for recognizing and promoting innovation on topics related to the human experience in buildings such as biophilia, enhanced comfort, personalized controls, and dynamically measured IEQ. And though studies are mixed on this point, most research shows that aspirational, certified green buildings outperform conventional ones in relation to measured and perceived air quality and reported satisfaction metrics.[11] However, we can still accomplish a lot toward emphasizing human performance and experience within the broader context of sustainability goals, and several challenges remain. They are discussed below along with some recommendations.

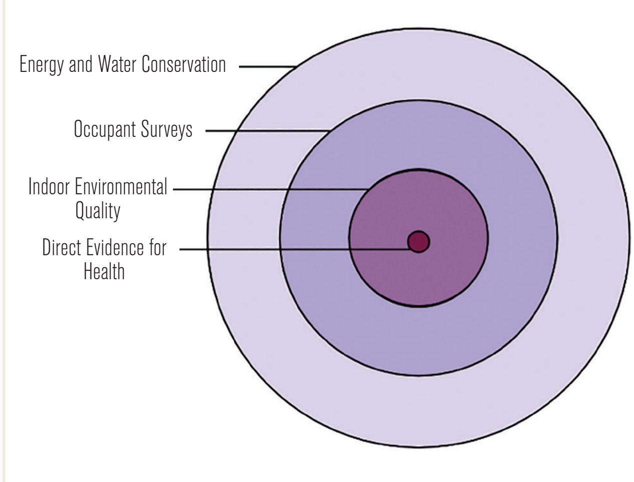
1. Overall, there is still a significant gap between relative emphasis on energy related features and those that focus on occupant health. A review of 100 green building case studies suggested that the most prevalent energy-saving strategies were observed in 80% of green buildings, while high indoor air quality was reported in only 30% of the buildings.[12]

2. Most of the existing standards lack established protocols for performance testing. The newest versions of LEED (version 4.1), along with the Arc performance tracking platform, reflect a priority on operational measures of IEQ and human experience. The most rigorous IEQ verification practice is available in the latest version of the WELL v2. However, though optimizations are available in WELL that require continuous monitoring, reporting and mitigation, the currently mandated measurements are episodic, and resource- and expertise-intensive.

3. Expectations and the ability to measure physical conditions is not yet matched by the development of methods for data analysis, scoring, interpretation, and communication. This points toward the obvious problem in which green buildings are often assumed to be healthy and beneficial for occupants; but without the performance data to support the aspiration. To address the challenge of designing the right set of indicators backed by an appropriate sampling scheme (what to measure, where, and how often), Allen, et al.[13] recommend the use of "Health Performance Indicators" and sketch an initial framework with example metrics. Vorosmarty, et al.[14] also emphasize the importance of impact measurement via science-based sustainability metrics, and make a case for context-based metrics.

4. Evidence that traditional green buildings contribute to improved productivity or health is sparse, and heavily reliant on subjective, self-reported and indirect means of health assessment, which are prone to information bias (*Figure 2*). A fundamental barrier is that quantitative insights into foundational, causal relationships between indoor exposures and health are hard to establish in real-world indoor environments. These environments are characterized by complex, mixed exposures and populations with differences in susceptibility and total exposure profiles across space and time. Moreover, green buildings face the added challenge that the unit return on investment (ROI) on specific IEQ interventions that improve already good conditions for non-vulnerable populations (e.g., typical office workers) is likely to be small; though the aggregate gains over large numbers of occupants and buildings could be significant. We need a framework for what constitutes minimal but sufficient evidence.

FIGURE 2 A qualitative illustration of the body of the existing literature on green buildings performed to date. As depicted, there is an abundant literature on the effectiveness of green buildings with respect to energy and water conservation. In contrast, evidence that traditional green buildings contribute to improved productivity or health for occupants is sparse.



Conclusion

Buildings providing an intentional combination of superior human experience and environmental performance will be recognized as better assets and come to define leadership in the real-estate industry. These "Tier 4" buildings create new challenges and opportunities for building professionals. While there are immediate opportunities for improving the uptake of IEQ features in green rating systems, broadening performance verification, optimizing the design of health-relevant indicators, enhancing diagnosis and response times, and building frameworks for integrated decision-making in building management, these "Tier 4" buildings will initially reflect a degree of experimentation and adaptive management.

We need studies that validate the expectation of ROI from improved IEQ under common scenarios in green buildings; especially where there are potential trade-offs between outcomes related to human health and well-being, convenience and comfort, and environmental impact. We need to collaborate to integrate across the findings, so resulting guidelines are cross-functionally consistent (e.g., across ventilation and filtration management, or energy and exposure reduction), parsimonious (e.g., a new performance verification could be used in lieu of a prescriptive requirement), and transparent on context (e.g., useful for a region with polluted outdoor air, or highly variable occupancy through the year, etc.).

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