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Editorial

New Approaches to Modelling Occupant Comfort

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Heating and cooling indoor environments is responsible for the largest share of energy consumption in buildings. Reducing the carbon footprint of the built environment relies on a balance of energy efficiency measures that simultaneously ensure occupant thermal comfort. Overlaying this challenge is a shift towards building designs and layouts that promote well-being, health and improve occupants' experience of their space. In this line of thought, long-standing paradigms focusing on thermal neutrality and steady-state conditions are being reconsidered. Recent interest in thermal alliesthesia as a framework to understand thermal perception (Parkinson and de Dear) [1] has reported different dimensions to occupant comfort (Schweiker et al., 2020) [2] than the prevailing models. In discussing the most suitable thermal exposures for human well-being, health and resilience, Schweiker (2022) [3] suggested three dimensions: relief, encouragement and enjoyment. Relief from thermal extremes—most close to neutrality—needs to be assured wherever necessary due to personal or contextual risk factors or demands. Second, enhancing well-being, health and resilience requires encouraging conditions outside thermal neutrality to stimulate human thermal adaptation. Third, enjoyment through thermal alliesthesia is not only an important driver of behaviour, but likely an exposure to counter thermal boredom and prioritise thermal delight (Heschong, 1979) [4].

With this Special Issue of *Buildings*, we wanted to focus on innovative research efforts to assess and model the thermal experience of building occupants. Successfully navigating this changing landscape requires novel approaches to understanding the psycho-physical relationship between thermal environments and occupant perception to increase the resilience of humans and buildings in a rapidly changing world. Applying new ways of conditioning buildings to support and assess these new concepts of thermal comfort is crucial to bridge the gap between research and practice. The six articles selected for this Special Issue address this context through their own means, presenting an exciting variety of research conducted in the field.

The first article addresses the methods to collect data from occupants and their environment to inform the development of models related to subjective thermal comfort. Collecting subjective responses was a time-consuming exercise in the past, but recent technological advancements enable new methods and opportunities. A novel approach presented by Jayathissa et al. (2020) [5] used smartwatches for "collecting intensive longitudinal subjective feedback". After developing the underlying technology, they were able to effortlessly collect several thousand survey responses within two weeks. The resulting dataset served as the basis to analyse participants thermal preferences and inherent variance. The conclusions highlight the need to go beyond "one-size-fits-all comfort models" towards individualised momentary approaches.

The second article presents another methodologically unique approach to collecting such thermal comfort data. Malakhatka et al. (2021) [6] evaluated the suitability of commercially available wearables to collect data from individuals while sleeping. Their overall research objective was to model the thermal conditions that best support increased sleep quality using wearable technologies. They performed a laboratory study to demonstrate

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the potential of their approach to collect meaningful data that can be used to develop recommendation models for optimal sleep environments. Such models could guide and support users in modulating their built environment to increase sleep quality.

Accurately modelling building energy use relies on careful consideration of occupant behaviour. Yet, these behaviours are difficult to reliably model due to a lack of understanding and supporting data. The third article by Uddin et al. (2021) [7] performed a systematic review of relevant behavioural studies of building occupants to summarise the current state of the topic. Their summary of 83 articles published in the past decade compared the different modelling approaches and the influence of certain parameters on occupant energy conservation behaviour. The paper concludes with an articulation of the research gaps to encourage and guide future research efforts.

The fourth article continues the thread of modelling occupant behaviour. Jeong et al. (2021) [8] developed a stochastic model of air conditioning usage based on field measurements in residential settings. Their dataset came from two years of measurements in 36 homes in Sydney, Australia. The resulting model predicted on/off events for heating and cooling using multivariate linear regression. They suggest that such a model could be used in building energy performance simulation to better represent residential air-conditioning usage patterns for both comfort and energy assessments.

One of the key deliverables of a building is acceptable thermal comfort for occupants. Ensuring comfortable environments has traditionally focused on static conditions within a narrow temperature range. This is an energy-intensive exercise that ignores compelling evidence in favour of dynamic thermal environments that vary with weather and climate. The fifth article by Pereira and Broday (2021) [9] used field measurements from university classrooms in southern Brazil to define new thermal comfort zones. They employed three methods of calculating the actual percentage of dissatisfied occupants to demonstrate that current international standards suggest warmer winter temperatures compared to their observations. Shifting indoor temperatures lower in winter would therefore save HVAC energy without impacting occupant comfort.

Energy efficiency measures in the provision of thermally acceptable conditions are important in reducing the carbon footprint of the built environment. Another complementary strategy is demand response programs to align available and required energy sources to reduce peak loads. The sixth article by Nazemi et al. (2021) [10] evaluated an optimisation approach that simultaneously considers the load profile, comfort requirements and the effect of incentives. They also include building assets such as washing machines and thermal assets for load shifting. The resulting algorithm was evaluated using a simulated community of multiple residential and commercial buildings. The evaluation of several scenarios shows the potential of community-level asset coordination to reduce peak loads and support future energy systems.

The variety of topics and methods in these six papers highlight the potential of novel technologies and innovative frameworks to model thermal comfort. Pairing high-quality data collection beyond laboratory settings with advanced analysis methods allows new and exciting insights into individual comfort requirements. Sophisticated models to predict these requirements during the building design stage, as well as applications to emerging settings such as demand response, show promise in supporting a balance between energy efficiency measures and occupant thermal comfort. Yet, we are far from understanding the balance between relief, encouragement and enjoyment required for human well-being and health. Greater research efforts looking beyond thermal neutrality and steady-state conditions towards the assessment of conditions promoting well-being, health and pleasure are needed to complete a holistic image of human thermal requirements within the built environment.

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References

1. Parkinson, T.; de Dear, R.J. Thermal pleasure in built environments: Physiology of alliesthesia. *Build. Res. Inf.* **2015**, *43*, 288–301. [CrossRef]
2. Schweiker, M.; Schakib-Ekbatan, K.; Fuchs, X.; Becker, S. A seasonal approach to alliesthesia. Is there a conflict with thermal adaptation? *Energy Build.* **2020**, *212*, 109745. [CrossRef]
3. Schweiker, M. Rethinking resilient thermal comfort within the context of human-building resilience. In *Routledge Handbook of Resilient Thermal Comfort*; Nicol, J.F., Roaf, S., Rijal, H.B., Eds.; Routledge: London, UK, 2022.
4. Heschong, L. *Thermal Delight in Architecture*; MIT Press: Cambridge, MA, USA, 1979.
5. Jayathissa, P.; Quintana, M.; Abdelrahman, M.; Miller, C. Humans-as-a-Sensor for Buildings—Intensive Longitudinal Indoor Comfort Models. *Buildings* **2020**, *10*, 174. [CrossRef]
6. Malakhatka, E.; Al Rahis, A.; Osman, O.; Lundqvist, P. Monitoring and Predicting Occupant's Sleep Quality by Using Wearable Device OURA Ring and Smart Building Sensors Data (Living Laboratory Case Study). *Buildings* **2021**, *11*, 459. [CrossRef]
7. Uddin, M.N.; Wei, H.-H.; Chi, H.L.; Ni, M. Influence of Occupant Behavior for Building Energy Conservation: A Systematic Review Study of Diverse Modeling and Simulation Approach. *Buildings* **2021**, *11*, 41. [CrossRef]
8. Jeong, B.; Kim, J.; Ma, Z.; Cooper, P.; de Dear, R. Identification of Environmental and Contextual Driving Factors of Air Conditioning Usage Behaviour in the Sydney Residential Buildings. *Buildings* **2021**, *11*, 122. [CrossRef]
9. Pereira, P.F.D.C.; Broday, E.E. Determination of Thermal Comfort Zones through Comparative Analysis between Different Characterization Methods of Thermally Dissatisfied People. *Buildings* **2021**, *11*, 320. [CrossRef]
10. Nazemi, S.D.; Jafari, M.A.; Zaidan, E. An Incentive-Based Optimization Approach for Load Scheduling Problem in Smart Building Communities. *Buildings* **2021**, *11*, 237. [CrossRef]