Colloquium on Applied Sciences 1 2025
20-24 January 2025, Faculty of Applied Sciences, UiTM Shah Alam, Malaysia

Transparent Wood in Sustainable Urban Architecture: Advancing Energy Efficiency and Smart City Integration

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Structured Abstract

Background: Transparent wood combines glass-like transparency with wood's sustainability and strength, derived from fast-growing species like balsa or birch through delignification and polymer impregnation. This innovative material exhibits low thermal conductivity, high durability, and a reduced carbon footprint compared to conventional glass and concrete, positioning it as a promising solution for energy-efficient urban architecture. Current small-scale applications include solar cells and prototype structures, while research explores flame-retardant coatings and enhanced properties. However, environmental impacts and scalability challenges remain understudied, necessitating a comprehensive assessment to unlock its potential as a sustainable material for climate-resilient architecture.

Literature Review: The study analyses the environmental, energy and functional advantages of transparent wood compared to conventional material like glass and focusing its application on various energy-efficient building designs for smart urban planning. Life cycle assessment (LCA) is demonstrated to evaluate environmental impact of transparent wood, including categories such as global warming potential, energy and water use, land use, and toxicity. Initial findings reveal that transparent wood outperforms glass in thermal insulation, reducing heat transfer by over four times and contributing to lower energy consumption in buildings. Challenges such as high production costs, scalability, and the reliance on specific wood types remain barriers to its widespread adoption. This research aims to assess the capability of integrating transparent wood into smart building technologies and identify strategies to overcome its technical and economic limitations. By addressing these challenges, this study seeks to point transparent wood as a promising alternative in urban architecture that helps reduce energy demand, mitigate urban heat island effects in urban areas, and advancing green construction practices.

Conclusion: Transparent wood offers a sustainable pathway for energy-efficient urban architecture but requires resolving scalability, cost, and regulatory challenges. Future efforts should optimize production, validate long-term performance, and integrate transparent wood into smart systems. Collaboration between policymakers and industries is essential to accelerate adoption, enabling transparent wood to drive greener, smarter cities.

Keywords: Transparent Wood, Energy Efficiency, Life Cycle Assessment, Smart Urban Planning, Sustainable Architecture

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