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## Sustainable phase change material developments for thermally comfortable smart buildings: A critical review

Aman Yadav<sup>a</sup>, Mahendran Samykan<sup>a,b,\*</sup>, Adarsh Kumar Pandey<sup>c,d,f</sup>,  
Sendhil Kumar Natarajan<sup>e</sup>, Gopi Vasudevan<sup>e</sup>, Guna Muthuvairavan<sup>e</sup>,  
Subbarama Kousik Suraparaju<sup>a,b</sup>

<sup>a</sup> Faculty of Mechanical & Automotive Engineering Technology, University Malaysia Pahang Al-Sultan Abdullah, Pekan, Pahang 26600, Malaysia

<sup>b</sup> Centre for Research in Advanced Fluid and Process, University Malaysia Pahang Al-Sultan Abdullah, Lebuhraya Tun Razak, Gambang, Kuantan, Pahang 26300, Malaysia

<sup>c</sup> Research Centre for Nano-Materials and Energy Technology (RCNMET), School of Engineering and Technology, Sunway University, No. 5, Jalan Universiti, Bandar Sunway, 8 Petaling Jaya, Selangor Darul Ehsan 47500, Malaysia

<sup>d</sup> Centre for Global Health, Saveetha Institute of Medical and Technical Sciences, Chennai, India

<sup>e</sup> Solar Energy Laboratory, Department of Mechanical Engineering, National Institute of Technology Puducherry, U.T. of Puducherry, India

<sup>f</sup> CoE for Energy and Eco-Sustainability Research, Uttarakhand University, Dehradun, India

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### ABSTRACT

The building industry is crucial in consuming vast quantities of energy in the modern era. Therefore, it is essential to carry out cutting-edge alterations to reduce energy usage and improve the energy performance of buildings. Thermal energy storage (TES) has become a principal point of investigation for researchers worldwide. Particularly in Phase change materials (PCMs) due to their significant advantages in strengthening energy efficiency, satisfying thermal comfort, and mitigating environmental pollution. Also, TES integrated with PCMs earns outstanding attention for its pivotal role in advancing energy conservation in building heating and cooling applications. Further, PCMs are incorporated in residential, commercial, and other building heating and cooling applications based on their reliance on heating and cooling methods. Hence, the present study provides an up-to-date analysis of recent academic research on TES management that utilizes PCMs for building heating and cooling. It explores the properties, characterization, and selection criteria determining their suitability for usage in building applications. Additionally, the thermal properties, incorporation techniques, factors that affect a building's energy efficiency, drawbacks of PCMs, and their alternative actions in building climate control are critically discussed. In addition, PCMs possible solutions for building applications and the policies of the PCMs to promote building thermal comfort are discussed comprehensively. Moreover, research investigations have demonstrated that incorporating PCMs has enhanced the energy efficiency of buildings, reduced energy costs, boosted heat retention, and maintained conformance to thermal comfort regulations. Therefore, PCMs integration in buildings can provide efficient solutions to issues arising from energy shortages, carbon emissions, and the significant environmental concerns they raise.

## 1. Introduction

### 1.1. Energy storage is vital

Buildings sectors consume about 151 EJ of energy, representing approximately 36 % of a total global final energy consumption compared to the other energy consumption sectors. According to the

authors, around 130 EJ, about 30 % of the world's energy consumption, is employed for building heating and cooling applications. The remaining 21 EJ are utilized for other building operations (Amin Mirjalili et al., 2023). Additionally, the building industry contributes to approximately 55 % of the total global electricity use. According to the effects of these fundamental variables, the worldwide use of electricity increased by 6.5 EJ or 19 % from 2010 to 2018. Also, the total energy consumption for lighting and appliances is 18 EJ, demonstrating an

\* Corresponding author at: Faculty of Mechanical & Automotive Engineering Technology, University Malaysia Pahang Al-Sultan Abdullah, Pekan, Pahang 26600, Malaysia.

E-mail address: [mahendran@ump.edu.my](mailto:mahendran@ump.edu.my) (M. Samykan).

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