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Editorial

Phase Change Materials for Building Energy Applications

Facundo Bre [1,*], Antonio Caggiano [2] and Umberto Berardi [3]

[1] Sustainable Urban & Built Environment Research Group, Luxembourg Institute of Science and Technology, L-4362 Esch-sur-Alzette, Luxembourg
[2] DICCA Department, University of Genova, via Montallegro 1, 16145 Genova, Italy; antonio.caggiano@unige.it
[3] ArCoD Department, Politecnico di Bari, via Orabona n.4, 71122 Bari, Italy; umberto.berardi@poliba.it
* Correspondence: facundo.bre@list.lu

Abstract

This editorial introduces the Special Issue entitled "Phase Change Materials for Building Energy Applications", which gathers nine original research articles focused on advancing thermal energy storage solutions in the built environment. The selected contributions explore the application of phase change materials (PCMs) across a range of building components and systems, including façades, flooring, glazing, and pavements, aimed at enhancing energy efficiency, reducing peak loads, and improving thermal comfort. This Special Issue highlights both experimental and numerical investigations, ranging from nanomaterial-enhanced PCMs and solid–solid PCM glazing systems to full-scale applications and the modeling of encapsulated PCM geometries. Collectively, these studies reflect the growing potential of PCMs to support sustainable, low-carbon construction and provide new insights into material design, system optimization, and energy resilience. We thank all contributing authors and reviewers for their valuable input and hope that this Special Issue serves as a resource for ongoing innovation in the field.

Keywords: phase change materials; thermal energy storage; building energy efficiency; PCM-integration; sustainable construction; building materials; experimental studies; numerical modeling; energy systems; climate-resilient buildings; carbon-neutrality

1. Introduction

The building sector is responsible for over 30% of global energy consumption and nearly 40% of total direct and indirect greenhouse gas emissions [1]. To address this, researchers in the building sector are increasingly focusing on innovative thermal management strategies [2]. Phase change materials (PCMs) have emerged as a particularly promising solution, enabling thermal energy storage and dynamic temperature regulation through latent heat processes [3]. Their integration into building components and systems, such as walls, floors, glazing, and HVAC, has been shown to improve energy efficiency [4,5], reduce peak demand [6], and enhance indoor thermal comfort [7].

Recent PCM developments have demonstrated substantial improvements in thermal storage capacity [8] and application versatility [9]. However, challenges remain in understanding their effectiveness in buildings, developing new integrated systems, and optimizing their thermal conductivity, long-term durability, and cost-effective manufacturing, thus making continued research essential.

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Received: 29 May 2025
Accepted: 24 June 2025
Published: 4 July 2025

Citation: Bre, F.; Caggiano, A.; Berardi, U. Phase Change Materials for Building Energy Applications. *Energies* **2025**, *18*, 3534. https://doi.org/10.3390/en18133534

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2. Paper Contributions

This Special Issue of *Energies* presents a curated selection of nine research articles that explore the design, application, technology deployment, and performance evaluation of PCMs across a wide range of building energy systems and components. The contributions collectively highlight both experimental and theoretical advances in the field.

Some studies examine PCM integration into traditional building elements, such as façade sandwich panels [10] and energy storage flooring for rural settlements [11], to enhance thermal inertia and reduce peak loads. Others investigate more advanced and emerging applications, including the use of nanomaterials to boost PCM conductivity [12], the optimization of glazing systems with solid–solid PCMs [13], and the deployment of PCM-based technologies in off-grid environments [14].

A significant emphasis is placed on PCM numerical modeling [13], encapsulation geometry and shape optimization [15], and real-scale performance assessments, as demonstrated in the studies on precast wall panels [10] and transpired solar collectors [12]. Additionally, novel materials such as carbon aerogels derived from citrus waste [16] and PCM-enhanced asphalt for pavements [17] showcase the broadening scope of PCM applications beyond conventional building envelopes.

3. Conclusions

Together, these contributions offer a comprehensive snapshot of current research and future directions for PCMs in building energy applications. This collection will serve as a valuable reference for academics, engineers, and policymakers working to advance the design of more energy-efficient and sustainable buildings.

We sincerely thank all contributing authors for their innovative work and the reviewers for their thoughtful evaluations and feedback. We also extend our appreciation to the *Energies* editorial team for their continued support.

We curated this Special Issue to highlight the growing potential of phase change materials in addressing energy efficiency and sustainability challenges in the built environment. We hope that this collection contributes meaningfully to the development of advanced building energy technologies.

Author Contributions: Conceptualization, F.B., and A.C.; writing—original draft preparation, F.B.; writing—review and editing, A.C. and U.B.; supervision, F.B. All authors have read and agreed to the published version of the manuscript.

Funding: Bre has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No. 101024627, as part of the 0E-BUILDINGS action project.

Data Availability Statement: No new data were created or analyzed in this study.

Acknowledgments: We thank the *Energies* editorial team for their support.

Conflicts of Interest: The authors declare no conflicts of interest.

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