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RESEARCH ARTICLE

Bio-based materials for energy efficiency in buildings: Insights & policy recommendations from the BIOBUILD Horizon Europe project

[version 1; peer review: 2 approved with reservations]

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Abstract

Buildings account for approximately 40% of Europe's energy consumption and 36% of greenhouse gas emissions, with heating and cooling representing nearly 80% of household energy use. The BIOBUILD project (2024–2027) addresses this by developing wood-based composites integrated with bio-based phase change materials (bioPCMs). Preliminary results indicate that these materials can reduce building energy demand by 6.5–12% while maintaining environmental performance comparable to conventional wood panels. This article explores the technical innovations, real-world performance modelling, and identifies the regulatory and market barriers to widespread adoption.

Keywords

Bio-based materials; energy efficiency; phase change materials; sustainable construction; building policy; circular economy

Open Peer Review

Approval Status ? ?

	1	2
version 1 15 Jun 2026	? view	? view

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Any reports and responses or comments on the article can be found at the end of the article.

This article is included in the Horizon Europe gateway.

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Author roles: Borri E: Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Bouhout N**: Supervision, Writing – Original Draft Preparation, Writing – Review & Editing; **Buyle M**: Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Cabeza LF**: Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Gritsch S**: Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Gutiérrez RÁ**: Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Moro A**: Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Palanti S**: Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Seuntjens H**: Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Terziev N**: Methodology, Project Administration, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; **Verbeke S**: Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

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Introduction

The transition to climate-neutral buildings requires a dual focus on reducing operational energy consumption and the embodied emissions of construction materials. Conventional materials such as concrete and synthetic insulation remain carbon-intensive. The BIOBUILD project supports EU objectives such as the New European Bauhaus and the Renovation Wave by promoting by promoting innovative materials that deliver measurable energy savings and improved indoor thermal conditions.

Preliminary results: Energy and environmental impact

BIOBUILD brings together European research and industry partners to develop three **natural binder systems that replace traditional fossil-based adhesives.** The first system, based on epoxidized linseed oil (ELO), produces a strong and durable bio-resin suitable for wallboards. The second uses lignosulfonates, enhanced with natural plasticizers, to increase flexibility and water resistance of the bio-composite. The third approach explores mycelia, the vegetative body of fungi to bind wood particles into lightweight, solid boards.

By exploring these systems, the project partners have created **prototype wallboards that combine the insulating power of wood with the heat-storage capacity** of bioPCMs. These materials absorb excess heat during the day and release it as temperatures drop, helping to stablise indoor climates and reduce the need for heating and cooling.

A technological breakthrough is the introduction of a **microwave-based curing process** for composites made with lignosulfonates, which shortens production time from several weeks to just a few minutes. This innovation makes large-scale, energy-efficient manufacturing more realistic. The materials have also proven compatible with both natural and commercial binders, paving the way for wider industrial adoption.

In testing, **hardwood substrates were found to perform best with mycelia-based systems**, achieving up to 50% of particles impregnated with PCM incorporated in the composite (see Figure 4). Thermal measurements showed that **heat transfer peaks during the phase change** (around 21 °C), providing valuable insight into how these materials store and release energy in real conditions (refer to *Deliverable 4.7 Report on the overall performance of produced flooring and wallboards available on the project website and zenodo*).

Material performance and market potential

To assess real-world performance, BIOBUILD researchers modelled a framework linking energy models and environmental impact analysis. Using dynamic building performance simulations showed that incorporating generic PCMs into the internal wallboards and flooring can reduce total energy demand by 6.5–12%, equivalent to 115–1,170 kWh per household each year (Gutiérrez *et al.*, 2026). The benefits vary with building design and are most pronounced in lightweight buildings, which are more sensitive to temperature fluctuations and summer overheating. The integration of PCMs can also effectively reduce indoor temperature peaks, improving overall thermal comfort (Verbeke *et al.*, 2025).

In parallel, a life cycle assessment (LCA) comparing lab-scale BIOBUILD panels with conventional medium-density fibreboard (MDF), particleboard and oriented strand board (OSB) was carried out. The results showed that the BIOBUILD prototypes perform within the same order of magnitude or even outperform conventional panels (see Figure 1). The analysis also highlights potential for further emission reductions through improved efficiency at industrial-scale production, biomass fuelling, and continuous processing.

Additional tests confirmed that ELO-based composites can incorporate up to 30% bioPCM while maintaining strong mechanical performance and low curing temperatures (as low as 60 °C), proving that high bio-content materials can match the performance of fossil-based alternatives (see Figure 2).

Thermal characterisation studies provided new insights into how BIOBUILD composites behave during phase change (Cabeza *et al.*, 2025). Using ethyl palmitate as the PCM, and polymerized lignosulfonate as a binder, the results showed a stable thermal conductivity of 0.13 W/mK in both the solid (10 °C) and liquid (40 °C) states. However, during the phase change range (20–25 °C), the material exhibited a notable 48% increase in effective thermal conductivity. This behaviour was linked to the heat absorption characteristics of the PCM as it transitions between phases.

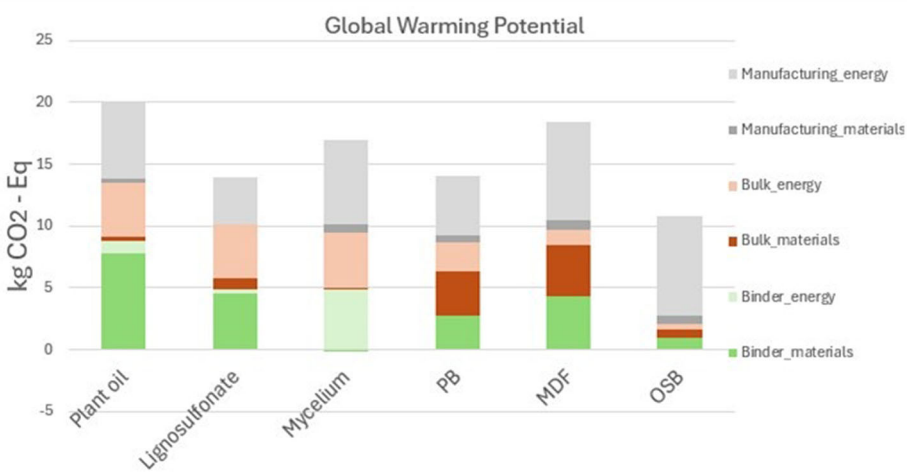

Figure 1. Global Warming Potential (GWP) comparison of different binder systems used in BIOBUILD composites. Functional unit: 1 m^2 of non-carrying indoor wallboards. Source: University of Antwerp.



Figure 2. Plant oil-based composite panels developed using epoxidized linseed oil (ELO) as a bio-based binder. Source: Swedish University of Agricultural Sciences (SLU).

The findings are significant, as most previous studies only measured PCM composites in their solid state, overlooking the dynamic changes during melting. By revealing how thermal conductivity peaks during phase change, this research on BIOBUILD samples offer valuable knowledge to improve the design and modelling of thermal energy storage (TES) systems and energy-efficient building materials (see Figure 5).

Beyond production and operational performance, the real-world impact of these materials also depends on maintenance requirements and how occupants interact with them. By helping stabilise indoor temperatures naturally, BIOBUILD solutions can reduce the use of energy while requiring minimal upkeep over time.



Figure 3. Lignin-based composite materials developed using lignosulfonates and natural plasticisers to enhance flexibility and water resistance. Source: Swedish University of Agricultural Sciences (SLU).



Figure 4. Fungal (mycelium-based) composites showing the use of fungal networks to bind wood particles into lightweight boards. Source: Swedish University of Agricultural Sciences (SLU).

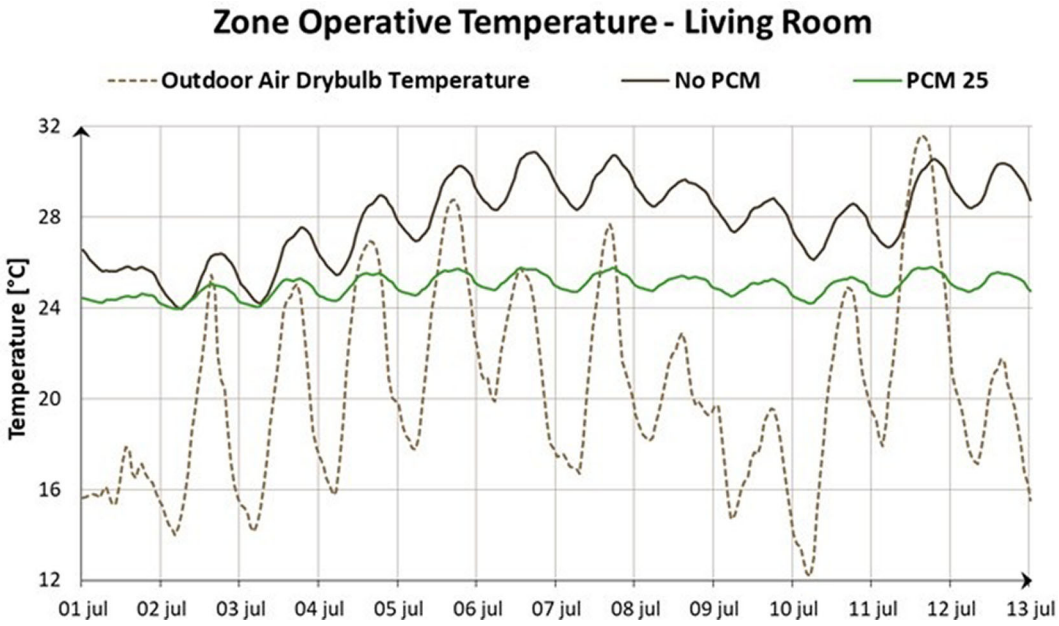

Figure 5. Effect of phase change materials (PCM) on living room operative temperature, demonstrating the thermal regulation capacity of PCM-integrated building materials. Source: University of Antwerp.

Table 1. Implementation roadmap for scaling bio-based building materials.

Phase	Policy action	Purpose
Short term	1. Develop common testing protocols and pre-standardisation guidelines for composites.	Establish comparable testing, support early regulatory recognition, and prepare the basis for a future EC mandate to ESOs.
Short term	2. Support pilot projects and demonstration buildings through EU and/or national funding instruments and green public procurement and integrate LCA to evaluate environmental burdens, benefits, and optimisation opportunities.	Generate performance evidence, raise TRLs, demonstrate real-world effectiveness, and enable low-cost process optimisation through early LCA insights.
Medium term	3. Integrate bio-based materials into EU regulatory and financial frameworks, including CPR, SPI, and the EU Taxonomy.	Unlock sustainable finance, enable market access, and increase industry confidence. EC could also issue a mandate to CEN/CENELEC to develop harmonised standards (hENs).
Medium –long term	4. Invest in industrialisation and process innovation, such as microwave curing and binder optimisation, renewable heat use to scale up production efficiently.	Reduce production costs, improve efficiency, and prepare large-scale manufacturing.
Long term	5. Embed life-cycle performance criteria in green building standards.	Create stable long-term market demand and support circular, low-carbon construction.

Market barriers and enablers

Despite promising results, several barriers must be addressed for bio-based PCM composites to reach widespread market adoption:

1. **Regulatory barriers**

   - The absence of harmonised testing and certification standards makes it difficult for new bio-composites to enter building codes or public procurement.

   - Approval pathways for innovative materials remain slow and complex.

2. **Economic barriers**

   - Current production takes place at small, experimental scales, which increases costs.
   - Industrial pilots and investment are needed to achieve economies of scale and lower prices.

3. **Technical barriers**

   - The construction sector is traditionally risk-averse and limited real-building demonstrations slow down adoption.
   - Developers and builders require transparent data on performance, safety, and durability.

4. **Market and cultural barriers**

   - The sector relies on familiar materials and established suppliers, making market uptake slow even when alternatives perform well.

5. **Circularity barriers**

   - Ensuring reuse, recycling, or safe biodegradation requires early-stage design planning.
   - Clear pathways for end-of-life treatment are still underdeveloped.

Policy pathways forward

Europe can accelerate the uptake of sustainable materials like those being developed in BIOBUILD by aligning regulation, funding, and market incentives. The actions below follow a logical sequence linked to the increasing maturity (TRL) of BIOBUILD materials. Each step reinforces the next, creating a coherent pathway from research to market deployment.

Conclusion

BIOBUILD demonstrates that combining bio-based materials with thermal function can deliver measurable energy savings and environmental benefits. These bio-based composites represent a new class of materials that are not only efficient and recyclable but also scalable for industrial production.

To realize their full potential, Europe must invest in standards, demonstrations, and industrial partnerships that bring these innovations from research to real buildings. Doing so will reduce emissions, lower energy use, and strengthen Europe's position as a leader in sustainable, circular construction.

Ethics and consent

Ethical approval and consent were not required.

Disclaimer

Views and opinions expressed are those of the authors only and do not necessarily reflect those of the European Union, European Research Executive Agency (REA), or Open Research Europe. Neither the European Union nor the granting authority can be held responsible for them.

Data availability

No data is associated with this article.

References

Cabeza LF, Mani Kala S, Ahmed W, *et al.*: **Evaluating effective thermal conductivity of PCM-impregnated wood composite at phase change temperature.** *J. Energy Storage.* 2025; **138**: 118788.
Publisher Full Text

Gutiérrez RA, Verbeke S, Audenaert A: **The Effect of Ventilation Control on Thermal Comfort in PCM-Integrated Dwellings.** Littlewood JR, Howlett RJ, Jain LC, editors. *Sustainability in Energy and Buildings 2024. SEB 2024. Smart Innovation, Systems and Technologies.* Singapore: Springer; 2026; vol. **113**.
Publisher Full Text

Verbeke S, Alvarez Gutiérrez R, Audenaert A: **Phase change materials as complementary retrofit strategy for energy efficiency: A simulation-based comparative analysis.** *6th International Conference on Building Energy and Environment, Eindhoven University of Technology, The Netherlands.* 2025, August 27.
Publisher Full Text

Open Peer Review

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Version 1

Reviewer Report 05 October 2026

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General Summary
This study presents applied research on the development of bio-based phase-change composite materials for the construction sector. This is an important topic given the significant impact of construction on planetary boundaries. The research contributes to efforts to make the construction sector more sustainable while improving indoor thermal comfort.
The article is clear and concise, but the results are presented rather briefly. This is somewhat frustrating, as the reader must refer to papers or conference proceedings published by the group in 2025 and 2026 to obtain further details.
The project partners report that the developed materials are suitable for industrial-scale implementation, which could make a significant contribution to the deployment of this new technology. The BIOBUILD project appears to be well aligned with European Union objectives in this field.
However, I have not independently verified the specific life-cycle assessment (LCA) data. Consequently, I cannot assess in detail the uncertainties associated with the reported results, particularly those concerning emission reductions attributed to improved efficiency at industrial production scale, biomass-based energy supply, and continuous processing.
Main Comments (Major Points)
Given the limited amount of data presented and the lack of detailed information on the methodology, it is difficult to assess satisfactorily whether the conclusions put forward by the BIOBUILD project partners are fully supported by robust data and whether the methodology is sufficiently reproducible.
Nevertheless, the quality of the journals and conferences in which related results have been published lends credibility to the conclusions. It would still be helpful to provide additional methodological details and supporting data, either in the main text or in supplementary material.
The graph showing the benefits of wood panels impregnated with phase-change materials illustrates the reported effect, but it is not sufficient on its own to robustly support the conclusions. A statistical table presenting relevant quantitative parameters, such as amplitude variations, correlations, and associated uncertainties, would strengthen the article.
Overall, a better balance should be achieved between the data presented directly in the article and

those available only through the cited literature, to provide the level of evidence expected in a scientific publication.
Similarly, the photographs alone are insufficient to substantiate some of the claims. For example, Figure 2 does not provide sufficient evidence to assess the long-term stability of the mechanical performance.
The policy recommendations are concrete and provide a useful set of basic actions for consideration at the European Union level.

Minor Comments

The quality of the photographs should be improved. In their present form, their scientific contribution is limited. Figures 1, 3, and 4 could potentially be grouped into a single composite figure.

AI Disclosure Statement

All scientific evaluations, conclusions, and structural critiques remain entirely the independent work of the reviewer. No manuscript files or data were uploaded to the AI system. [1, 2]

Is the work clearly and accurately presented and does it engage with the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

Are all the source data and materials underlying the results available?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Not applicable

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: thermodynamics, environmental and energy engineering, bio-inspired systems, and the analysis of complex open systems at ecological, building, and territorial scales.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 19 August 2026

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The manuscript provides a concise and accessible overview of the BIOBUILD project, summarising its main technological developments and their potential implications for building energy performance, environmental impact and future market uptake. The inclusion of policy recommendations is also a useful component of this type of brief, project-oriented article. The manuscript is generally clear and well structured; nevertheless, some aspects would benefit from further clarification or more precise wording.

- The reported energy savings of 6.5-12% require further contextualisation. Although the *Abstract* may suggest that these values correspond to the wood-based bioPCM composites developed within BIOBUILD, the manuscript later indicates that they were obtained from dynamic building performance simulations using generic PCMs. Moreover, the systems considered in the cited study differ from the BIOBUILD materials discussed here: the PCMs were macroencapsulated, were not integrated into the developed wood-based composites, and were not bio-based. This distinction should be made explicit both in the *Abstract* and in the *Material performance and market potential* section to avoid attributing these energy savings directly to the BIOBUILD composites. Since the reported range also depends on the conditions considered in the simulations, some brief context on the main factors influencing these results would be useful, particularly climate, ventilation strategy and PCM configuration/content. The role of ventilation should be acknowledged, as it has an important influence on the performance reported in the cited study.
- The manuscript briefly introduces the three binder systems investigated within BIOBUILD (ELO, lignosulfonates and mycelium), which helps the reader understand the composition of the developed composites. A similarly brief description of the bioPCM used in the project would be helpful. In particular, the authors could indicate its origin and composition, physical form, type of phase transition (e.g., solid-liquid or solid-solid), transition temperature range, and how it is incorporated into the different composite systems. This would provide the reader with a clearer picture of the materials referred to throughout the manuscript.
- The origin of the data presented in Figure 5 should be clarified. From the current text and caption, it is not clear whether the operative temperature profiles correspond to modelling results, experimental measurements from a pilot-scale system, or monitoring under real conditions. It should also be indicated whether the PCM was incorporated into the wood-based panels developed within BIOBUILD or used in another configuration. In addition, the caption should briefly define what “PCM 25” refers to, presumably the PCM transition or melting temperature.
- The policy recommendations and implementation roadmap are a relevant component of the manuscript. However, it would be useful to briefly indicate how the identified barriers and proposed actions were derived, for example whether they reflect findings from the BIOBUILD project, stakeholder or industry input, regulatory analysis, or previous literature. This would provide some context for the recommendations without requiring a detailed methodological discussion.

- Some statements in the *Conclusion* section could be slightly moderated to remain consistent with the challenges discussed in the manuscript. In particular, describing the developed composites as “recyclable” and “scalable for industrial production” appears somewhat conclusive, while end-of-life pathways and industrial-scale production are still presented as areas requiring further development. Wording that reflects their potential for recyclability and industrial scale-up may be more appropriate at the current stage of the project.
- Finally, as a minor editorial point, the Introduction contains a simple wording error in the expression “by promoting by promoting innovative materials”, where “by promoting” is repeated.

Is the work clearly and accurately presented and does it engage with the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Sustainable materials; energy efficiency; environmental assessment

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.