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Policy Brief

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Bio-based Materials for Energy Efficiency in Buildings - Insights & Policy Recommendations from the BIOBUILD Horizon Europe Project

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Publishable Summary

Buildings are responsible for around 40% of Europe's energy consumption and 36% of greenhouse gas emissions. Most of that energy, nearly 80% in homes, is used toward heating and cooling. Reducing both operational and embodied emissions is essential to achieving the EU's 2050 climate neutrality goals.

The BIOBUILD project is developing next generation wood-based building materials that store and release heat naturally. By combining renewable wood, plant oils, lignin and mycelia with bio-based phase change materials (bioPCMs), BIOBUILD is creating composites that improve indoor comfort and reduce thermal energy use. BioPCMs are natural substances that absorb and release heat as they melt and solidify.

Project results show that integrating bioPCMs into wood-based wallboards and flooring can reduce building energy demand by 6.5–12%, while maintaining environmental performance comparable to conventional wood panels. Beyond technical feasibility, BIOBUILD identifies regulatory gaps, scale-up challenges, and market barriers that currently limit adoption. The policy recommendations presented in this brief outline a phased pathway, from testing and pilot projects to regulatory integration, to support the uptake of bio-based, energy-efficient building materials across Europe.

Disclaimer

This policy brief presents preliminary results from the BIOBUILD project, which is currently mid-way through its implementation. The findings reflect the status of research and testing at the time of publication and may evolve as the project progresses. Final results will be presented in the end-of-project white paper.

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Background

The transition to climate-neutral buildings requires addressing both how much energy buildings consume, and the materials used to construct them. Conventional materials such as cement, concrete, and synthetic insulation are highly carbon-intensive, while steel, though widely recycled, remains energy-intensive to produce.

The BIOBUILD project (2024–2027) responds to this challenge by exploring how wood-based composites enhanced with bio-based phase change materials (bioPCMs) can help the European transition toward sustainable and energy-efficient building stock. This is therefore essential to meeting the objectives of the New European Bauhaus, Clean Industrial Deal, the Circular Economy Action Plan, and the Renovation Wave. The project further contributes to the implementation of the Energy Performance of Buildings Directive (EPBD) and supports the EU's Construction 2050 Roadmap by promoting innovative materials that can deliver measurable energy savings, improved indoor thermal conditions and climate benefits.

The BIOBUILD Innovation: Key Findings

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. 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 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

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demand by 6.5–12%, equivalent to 115–1,170 kWh per household each year[1]. 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[2].

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. The analysis also highlights potential for further emission reductions through improved efficiency at industrial-scale production, biomass fuelling, and continuous processing.

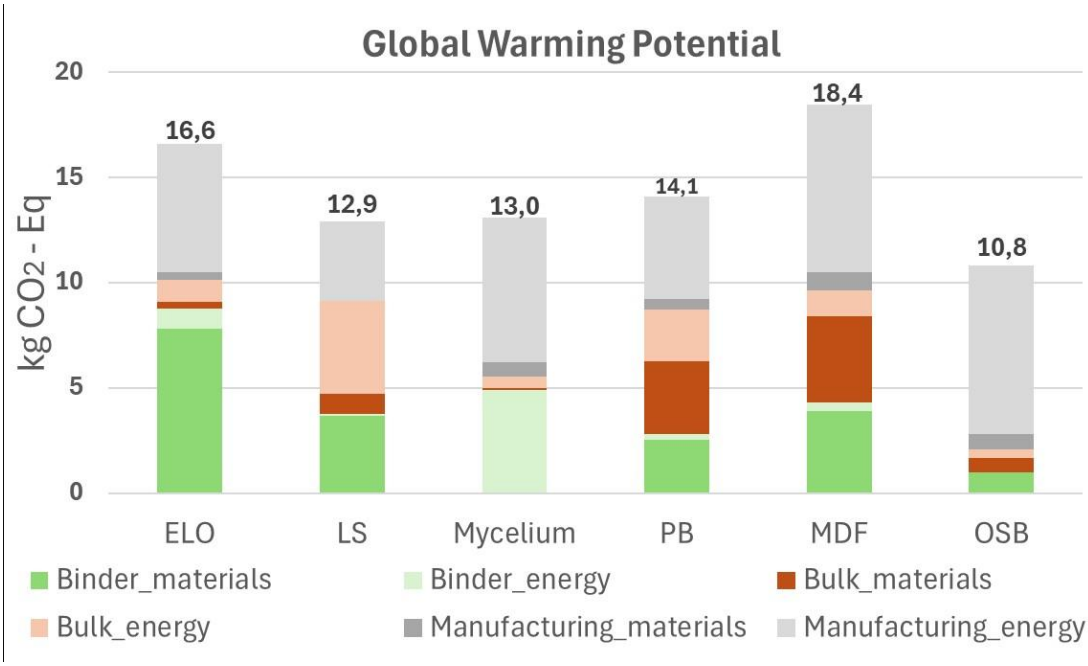

Figure 1 GWP Comparison of Different Binders. Functional Unit: 1m² of non-carrying indoor wallboards cc University of Antwerp

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 (refer to Deliverable 3.1 Report on optimal conditions for plant oils-based binder).

[1] Gutiérrez, R.A., Verbeke, S., Audenaert, A. (2026). The Effect of Ventilation Control on Thermal Comfort in PCM-Integrated Dwellings. In: Littlewood, J.R., Howlett, R.J., Jain, L.C. (eds) Sustainability in Energy and Buildings 2024. SEB 2024. Smart Innovation, Systems and Technologies, vol 113. Springer, Singapore. https://doi.org/10.1007/978-981-96-5069-9_40

[2] Verbeke, S., Alvarez Gutiérrez, R., & Audenaert, A. (2025, August 27). 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. https://doi.org/10.5281/zenodo.16959645

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Figure 2 Plant Oil Composites cc SLU *Figure 3 Lignin Composites* *Figure 4 Fungal Composites*

Thermal characterisation studies provided new insights into how BIOBUILD composites behave during phase change[3]. 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.

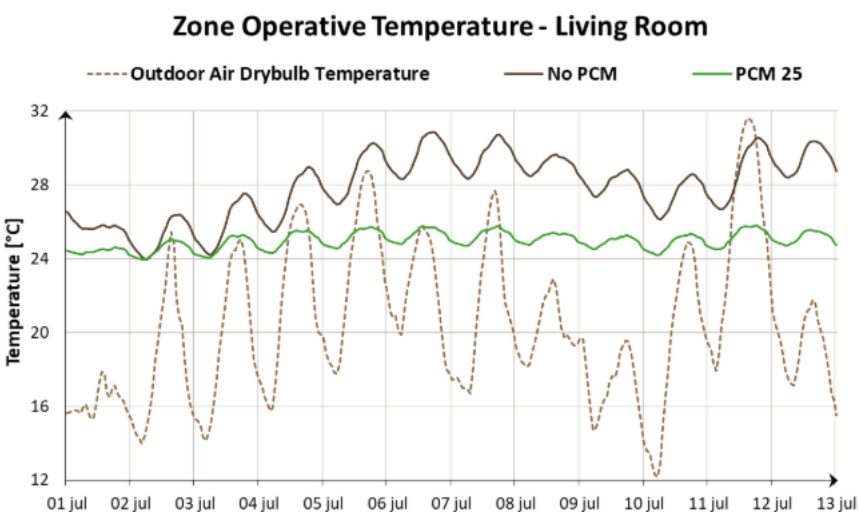

Figure 5 Effectiveness of Phase Change Materials (PCM) on Living Room Operative Temperature cc University of Antwerp

[3] Cabeza, L. F., Mani Kala, S., Ahmed, W., Nazari, M., Terziev, N., Bischof, S., Gritsch, S., Borri, E., & Zsembinszki, G. (2025). Evaluating effective thermal conductivity of PCM-impregnated wood composite at phase change temperature. Journal of Energy Storage, 138, 118788. https://doi.org/10.1016/j.est.2025.118788

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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.

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.

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

Policy actions based on findings from the BIOBUILD project (2024–2027):

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.

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	Generate performance evidence, raise TRLs, demonstrate real-world effectiveness,

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	and green public procurement and integrate LCA to evaluate environmental burdens, benefits, and optimisation opportunities.	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.

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.

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