



DELIVERABLE D3.5

DEVELOPMENT AND SCALING-UP OF

MYCELIUM PANELS



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1. Introduction

Deliverable 3.5 of INBUILT Work Package 3 (WP3) outlines the progress in developing and scaling up mycelium-based panels, an innovative thermal insulation material created by project partner MYKOR. This material—composed of industrial by-products, mycelium, and a nano-coating—will be advanced from TRL5 to TRL8, following predefined performance benchmarks.

Throughout the development process, specifications for raw material quality will be established. The influence of manufacturing methods on material quality (covered in WP5) and the final product's performance will be evaluated. Real-world testing will take place in two demonstration buildings, aligning with the objectives of Work Package 6 (WP6). The insulation solution is intended for use in internal and external walls.

The construction industry—including the production of building materials—contributes approximately 5–12% of total greenhouse gas emissions across EU nations. In this context, **MykoFoam offers a credible solution for reducing the sector's carbon footprint**. Today's insulation market is heavily dominated by plastics (55%) and mineral wools (37%), while truly sustainable, high-performance, and affordable alternatives remain limited. Many so-called eco-insulations either underperform or rely on virgin raw materials. **MykoFoam breaks this pattern**, delivering a bio-based solution with **excellent thermal performance, strong fire resistance (Class C), and competitive pricing**—proving that sustainability doesn't have to come at the cost of safety or efficiency. **Mykor** is pioneering the development and scale-up of next-generation insulation materials that emphasise both environmental responsibility and human well-being. Our innovative solutions are engineered to meet the latest EU standards on fire safety and embodied carbon, addressing a critical gap in a market still reliant on outdated materials. Traditional insulation products present serious limitations—polystyrene carries significant fire hazards and emits toxic gases, while mineral wool, though fire-resistant, is highly carbon-intensive and dependent on non-renewable resources.

Mykor offers a breakthrough alternative: a sustainable, mycelium-based sheet insulation that combines high performance with minimal environmental impact. Our flagship product, MykoFoam is made from waste biomass and engineered for enhanced fire safety, achieving Class C performance with good water absorption properties and vapor transmission results, low in carbon emissions, and cost-effective.

Through the **INBUILT** project, we aim to further improve the thermal performance of MykoFoam, targeting a lambda value of 0.038 W/m·K in the beginning of the project. Fire safety performance targetted to reach Class B. Enhanced durability and moisture resistance have been achieved via advanced coating techniques. Process optimisations pursue a significant increased pilot-scale production efficiency, with the ultimate goal for INBUILT for the product to move toward **Technology Readiness Level (TRL) 8**, indicating readiness for market launch.

The INBUILT initiative specifically focuses on the development of a cellulose-based thermal insulation material that incorporates mycelium—transforming paper industry residues into a high-value resource instead of being incinerated or converted into low-value biofuels. Early prototypes reveal that the integration of mycelium improves both thermal insulation and acoustic performance. The ultimate goal is to prepare for a commercially viable, fully manufacturable insulation product made entirely from industrial by-products, offering performance comparable to the best bio-based alternatives on the market.

We also aim to achieve continuous large-scale production of mycelium materials—something that other competitors in the field have struggled to accomplish.

2. Product development workflow

The objective of Task 3.5 is to develop bio-based, recycled, and low-carbon thermal and acoustic insulation sheet panels or infill (Product IP #9). These panels are produced by **Mykor**, whose materials are made entirely from cellulosic waste by-products sourced from the paper industry. The waste is binded using fungal mycelium—the **root-like structure of mushrooms**—which serves as a natural binder.

Mykor employs a combination of cellulosic waste and a specific fungal strain selected for its desirable properties as an alternative to polystyrene, offering good fire safety and good thermal insulation while drastically reducing embodied carbon. The production process begins with the collection of quality-controlled cellulosic waste from **The Navigator Company**, an international pulp and paper company, a key partner. Upon arrival at the factory, the waste undergoes processing to remove non-cellulosic material, followed by sterilization (autoclaving). It is then mixed with the fungal binder and grown in vats. The growing material is shaped in moulds based on the required thickness and cured over a total cycle of five weeks in controlled incubation and dry rooms. Finally, the product is coated with a nano-membrane (currently under development) and stabilized for improved durability and weather resistance. Imagine a fusion of a mushroom farm, agricultural waste and a manufacturing line.

This innovation enables the scalable production of low-carbon, renewable insulation materials that match the performance of synthetic, non-renewable alternatives.

Target Applications

The developed insulation product is intended for thermal and acoustic applications in buildings, particularly:

- For filling enclosed voids within both interior and exterior walls of timber-framed buildings and comparable construction types
- For placement within the gaps between wooden rafters, joists, and similar structural cavities

Performance and Circularity Goals

At the project's outset, key hygrothermal performance targets (see Table 1) and sustainability indicators related to circularity (see Table 2) were defined to guide development.

Table 1 Product target KPIs

Product performance target characteristics	Target value
Insulation performance improvement	Mycelium cellulose boards $\lambda \leq 0.038 \text{ W}/(\text{m.K})$
Expected Indoor hygrothermal comfort enhancement	Surface temperature of the original walls will be higher in winter (e.g. 19°C) reducing cold wall sensation and improving thermal comfort
Expected Indoor acoustic comfort enhancement	Mycelium cellulose boards: Noise reduction coefficient = 0.53 [ISO 354]
Expected fire performance	Euroclass B
Expected Energy demand reduction	-35% to -55% for renovation cases (depends on insulation thickness and building typology)
Fabrication and installation Cost reduction	18€ per m ²
Estimated time for a fully certified product	6-8 months after project

Table 2 Circularity KPI

Key circularity KPI	Target value
KPI#5 -% of bio & geo-sourced material	100%
KPI#6 -% of reused material	50%
KPI#7 - % of recycled material	100%
KPI#8 - % of reusability of the products	50%
KPI#9 - % of recyclability of the products	100%
KPI#5 -% of bio & geo-sourced material	100%

2.1 Substrate selection

1 – Industrial Residues from the Paper industry

Industrial by-products sourced from leading pulp and paper producers, including The Navigator Company and CELBI S.A. (Fig 1), are delivered directly to our facility as primary feedstock (Fig 2). These materials undergo dedicated sieving process and sterilisation to meet our production standards. Additionally, we

incorporate selected organic residues from the brewing industry, further enhancing the circularity and sustainability of our supply chain.



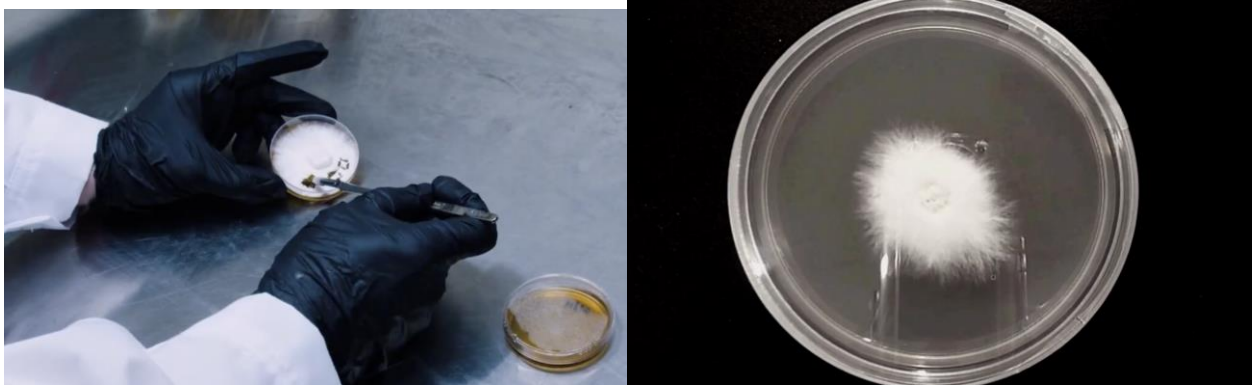
Fig 1. Quality-controlled cellulosic waste from our substrate partners, used as our primary material.



Fig 2. Mykor facilities (Left). Process detail (Right).

2 – Mycelium, mushroom roots

The processed substrate is subsequently inoculated with mycelium through a proprietary biotechnology process, wherein the mycelium acts as a natural binder for the composite material. Cultivated in-house, our mycelium strains are subject to rigorous quality control protocols, recognizing the dynamic nature of this living organism. We have refined contamination detection methods and successfully adapted mycelium species to thrive in industrial-scale production environments, ensuring consistency, resilience, and performance. (Fig 3.)



(Fig 3) We cultivate our own mother spawn and utilize specially engineered mycelium strains that are optimized for enhanced strength and suitability at an industrial scale.

3 – Fire- Retardant Nano-coatings

Throughout Task 3.5, we developed and tested multiple formulations aimed at enhancing the fire resistance of our product while minimizing CO₂ emissions. Our R&D chemists have iteratively refined several generations of coatings, ultimately arriving at a final formulation designed to lower both the Global Warming Potential (GWP) and cost per square metre (£/m²). This development process placed a strong emphasis on durability, with a particular focus on resistance to humidity and surface abrasion, resulting in a robust and efficient coating solution. (Fig 4.)



Fig 4. Factory tests during coating development and application tests.

Throughout the course of WP3, we developed and evaluated two generations of our insulation panels. Generation 1 (HD) featured a high-density composition, utilizing a greater quantity of substrate to achieve structural robustness. Generation 2 low density (LD) focused on process optimization to produce a lighter panel while enhancing thermal performance. Following extensive testing and performance benchmarking,

Generation 2 emerged as the optimal solution. These panels exhibit a density of 63 kg/m³ and are manufactured in standard dimensions of 120 cm x 60 cm, with thicknesses of either 10 cm or 5 cm. (Fig 5).



Fig 5. Factory-produced samples and multiple batch variations were displayed for comparison.

2.2 Product Development: Formulation, Optimization, and Prototyping

As part of the product development process, two prototype mycelium insulation products were tested, each incorporating variations in substrate composition, density, and nano-coating applications. These prototypes were compared to assess thermal performance, with a focus on thermal conductivity as the primary performance parameter, as presented in Table 3.

Testing was carried out at two separate institutions: the University of Bath, a consortium partner, and Itecons – Construção, Energia, Ambiente e Sustentabilidade, a Portuguese subcontracted responsible for certification and testing. It is important to note that the samples tested at each institution originated from different sources, from Mykor R&D lab and Factory. Bath have conducted tests at different environmental conditions (and different temperature differences) and for panels that have been preconditioned. Itecons used lower temperature difference and panels were conditioned for 24hr at 23/50 - Bath tests conditioned dry, 50% and 80%. Despite the difference in production sites, both followed the same standardised manufacturing procedures.

The results demonstrate an excellent level of concordance between the two institutions, which is to be expected given that both employ comparable steady-state measurement techniques, namely the Heat Flow Meter and Guarded Hot Plate methods—renowned for their high repeatability and precision.

The consistency in test results across both institutions demonstrates the reliability of the production process. Minor variations observed in the results were attributable only to differences in equipment or testing conditions, such as temperature. (Tab 3.)

Tab 3. Preliminary thermal conductivity measurement results of Prototype 1 & 2.

Tester	Label	Thermal Conductivity	Density	Average Temperature	Temperature Difference
Uni of Bath	M162/DRY	0.04769± 0,0025	183.4	10	20
Uni of Bath	M163/50	0.05162± 0,0025	192.0	10	20
Uni of Bath	M222/UC	0.04554± 0,0025	74.0	10	20
Uni of Bath	M223/UC	0.04497± 0,0025	70.0	10	20
Uni of Bath	M224/UC	0.04549± 0,0025	93.0	10	20
Itecons	OMH183A/24	0.04190± 0,0025	62.5	10	15
Itecons	OMH184A/24	0.04190± 0,0025	66.5	10	15
Itecons	OMH178A/24	0.05180± 0,0025	188.2	10	15
Itecons	OMH198A/24	0.04450± 0,0025	73.5	10	15

The preliminary thermal conductivity measurements reveal a significant difference between Prototype 1 and Prototype 2. As detailed in Table 3, this disparity is largely attributed to variations in sample formulation, particularly the cellulose content, which directly influences density. When comparing 50 mm thick samples, the first-generation product (Prototype 1 – HD) was considerably denser and heavier than the second-generation product (Prototype 2 – LD).

Within each prototype, the thermal conductivity values of samples with identical thicknesses showed minimal variation, indicating consistent performance across replicates. However, due to the substantial difference in density between the two prototype types, a notable divergence in thermal conductivity was observed.

When comparing samples of similar density, Itecons recorded a thermal conductivity of 0.04450 W/m·K for a specimen with a density of 73.5 kg/m³, while the University of Bath measured 0.04554 W/m·K for a 74 kg/m³ sample. Based on these findings, we have concluded that the LD panels (Prototype 2) will be prioritized for further development, as they demonstrated superior thermal performance. (Fig 7).

While we did not reach our initial target of 0.038 W/(m·K), we consider the achieved thermal conductivity of 0.0419 W/(m·K) to be a significant accomplishment—particularly when benchmarked against other bio-based alternatives in the market - you can see a comparison on section 4. *Table 4. Comparison of #IP9 indicators with other competitive products.* Moreover, we have established a robust and repeatable manufacturing process to ensure the consistency and reliability of this performance metric.



Fig 7. LD panels (low density – prototype 2) being applied on the wall. With application we could also see these were the best examples, as they were lighter and easy to apply.

During these tests, the final coating was not applied to the panels, as it underwent several iterations throughout the development process. The final version—selected for use in demonstration projects and ongoing product development—was chosen based on its strong adhesion and fire-retardant performance. This coating will be tested in combination with the selected prototype formulation during chamber testing at the University of Bath, scheduled for July 2025.

3. Scaling-up of mycelium insulation panels

3.1. Advanced Sample Fabrication Process

Mykor’s manufacturing process has undergone a significant evolution, driven by continuous research, prototyping, and performance testing. The company has moved from early-stage, lab-scale experimentation to a more refined and scalable production model (Fig 6). Key improvements include the optimization of substrate formulations, refinement of growth conditions, and the development of standardized moulding techniques to ensure consistency and quality across batches. Additionally, Mykor has streamlined the integration of nano-coatings and surface treatments to enhance product durability and thermal performance. These advancements have enabled the transition from prototype to pre-commercial manufacturing, positioning Mykor to meet the demands of both pilot projects and future large-scale applications.

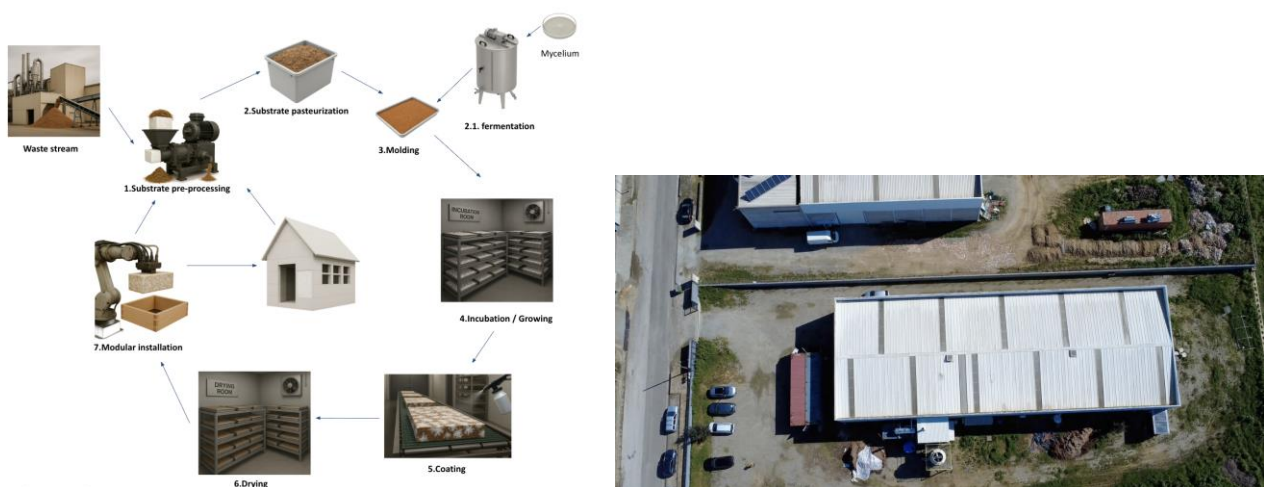


Fig 6. Mykor manufacturing process

Improved samples were produced in 600 x 1200 mm sheets, with a thickness of 50 mm. Mykor is still performing tests on samples with a thickness of 100 mm, as they significantly take more lead time. (Fig 7.) A significant volume of square meters was manufactured to meet the high demand for various testing samples. Due to changes in formulation and the ongoing scale-up of several key processes—such as substrate pre-treatment, moulding, and coating application—it was challenging to achieve consistent production quickly. These scale-up efforts are also financially intensive. Despite these challenges, we have maintained a steady production rate of 30.2 m² per month.



Fig 7. Sample of 600 mm x 1200 mm with 100 mm thickness

Substrate preparation remains one of the most critical stages, particularly in isolating the fibrous fraction from our feedstock to produce lower-density panels. This step has a direct impact on the overall quality and consistency of the final sheets. Additionally, working with living organisms introduces further complexity, requiring temperature-controlled environments to avoid contamination during incubation. We have invested considerable effort in addressing these issues and are proud of the consistent quality we have achieved in producing LD (low-density) panel batches. (Fig 8.)

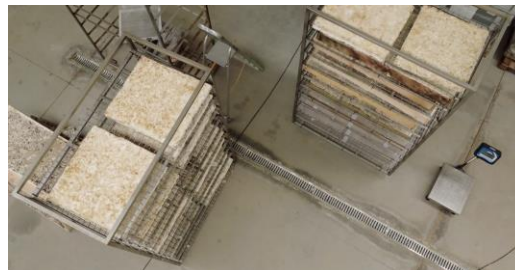


Fig 8. Sample batches in factory

3.2 Testing to Characterize Mechanical Behaviour and Performance

To evaluate the performance of Mykor's insulation panels against other commercially available thermal insulation materials, test criteria were defined in alignment with the European Assessment Documents (EADs) EAD-040005-00-1201—relevant to CE certification of natural fibre-based insulation—and EAD-040288-00-1201, which applies to polyester fibre insulation products. These standards establish a robust methodology for ensuring comparability and regulatory compliance.

Performance benchmarks were identified by referencing both the criteria laid out in the EADs and the technical specifications of comparable solutions currently on the market. For this comparative analysis, Mykor selected a wood fibre wool panel as the reference product.

Testing activities were carried out in collaboration with partners from the INBUILT project, specifically under Task 3.7 of Work Package 3 (WP3), which focuses on performance verification and material validation. In this context, the University of Bath (UBATH) assessed a prototype of Mykor's bio-based insulation panel. The testing campaign involved laboratory analysis of various material attributes, including thermal conductivity, specific heat capacity, water uptake, vapour permeability, bulk density, compressive behaviour, and dimensional consistency. A comprehensive account of the testing methods and findings will be found in Deliverable 3.7 (M24), to be compiled by the University of Bath.

For the remaining performance assessments, external laboratories with the necessary technical expertise were engaged to conduct the required tests. *Itecons* was subcontracted to carry out evaluations related to fire behaviour and acoustic properties, including reaction-to-fire classification and sound absorption measurements. Additionally, complementary acoustic testing will be performed by Politecnico di Bari, following a recommendation from the University of Bath, done in T3.7.

Moisture absorption

The moisture storage function, or water vapour sorption isotherm, describes the relationship between the equilibrium moisture content (EMC) of a material and the relative humidity of its environment. The measurement procedure is described in BS EN ISO 12571 (2021). The specimen EMC was measured in steps of increasing relative humidity, from dry increasing to as close to 100% as described in the test method, and then again in decreasing steps. Measurements are temperature dependent and therefore conducted in isothermal conditions. EN 12571 specifies a reference temperature of $23 \pm 0.5^\circ\text{C}$.

Testing was conducted in University of Bath using an Intrinsic Dynamic Vapour Sorption (DVS) Analyser, which considerably reduces testing periods compared to standard desiccator and climate chamber methods, with improved control of test conditions. EMC was determined at relative humidity setpoints of 0%, 20%, 50%, 70%, 80%, 85%, 90%, 95% and 98% at 23°C for both adsorption and desorption isotherms.

Water absorption

Tests to determine the water absorption coefficients by partial immersion have been conducted according to BSEN ISO15148 (2002). Test specimens were sealed on the lateral sides to promote one-dimensional liquid transport. One surface of each test specimen is then placed in contact with liquid water, rested on supports, and the rate of absorption is measured as a function of time by periodic weighing (Figure 7). Testing is

completed either when water appears on the top surface of the specimens, the increase in mass is less than 1 g/m² of face area after 8 h, or after 24 hours. Three specimens were tested for each material. The water absorption coefficient is determined by first calculating the increase in mass from the initial mass at each weighing divided by the surface area perpendicular to water transport. This is then plotted against the square root of the time, which usually gives a linear relationship, with the water absorption coefficient (A_w) being the gradient.

Based on the provided information, MykoFoam HD exhibits a water absorption coefficient of **0.009 ± 0.002 kg/m²·s^{0.5}**, attributed to the mycelium skin formed on its surface. This performance can be compared to other common insulation materials as follows:

- **Expanded Polystyrene (EPS):** EPS materials have water absorption coefficients ranging from **0.03 to 0.1 kg/m²·s^{0.5}**, depending on density and manufacturing processes. ¹
- **Mineral Wool:** Mineral wool insulation exhibits higher water absorption, with coefficients around **0.038 kg/m²·s^{0.5}**. ²

These comparisons indicate that MykoFoam HD has a significantly lower water absorption rate than both EPS and mineral wool, suggesting superior moisture resistance. This characteristic makes it a promising alternative for applications requiring insulation materials with enhanced moisture resistance.

Vapour transmissionThe HD panels demonstrated water vapour diffusion resistance factors of 3.1 (dry cup) and 2.6 (wet cup). University of Bath will still test lower density panels, if it is availability. The development of our second-generation, lower-density product led to increased porosity, which corresponds with the observed improvement in water vapour permeability with tests being performed in Itecons. This greater internal void space enhances air and moisture transfer through the material, confirming expectations for a more breathable and efficient insulation solution.

The tested conducted in Itecons regarding vapour transmission, our second generation of product, LD insulation sample, demonstrates very high vapor diffusion resistance ($\mu = 2907$) and moderate vapor permeability ($\delta = 0.49$), with consistent and reliable results across multiple test replicates. These properties make it particularly well-suited for environments where vapor control is essential, such as in building envelopes—walls or roofs—where preventing condensation and moisture buildup is critical. This is especially important in colder climates or high-humidity interior spaces. (Tab 4.)

Tab 4. Vapour transmission *measurement results of Prototype 1 & 2.*

Property	LD (ISO068-25)	HD (ISO069-25)	Interpretation
Thickness	50 mm	50 mm	Same thickness ensures direct comparability

Permeability (mg/(m-h-Pa))	0.49 ± 0.014	0.40 0.029	LD is slightly more permeable to water vapor
Permeance (mg/(m ² -h-Pa))	0.10 ± 0.0061	0.13 0.0067	HD allows more vapor to pass per surface area
Resistance to Vapor(Z) (m ² -h-Pa)/mg)	2.5	2.51	HD has huger resistance to vapor flow overall
Diffusion Resistance Factor (μ)	7,33 ± 0,17	5,60 ± 0,18	HD is more resistant to vapor diffusion (more closed structure)
Equivalent Air Layer Thickness (Sd)	0.35	0.28	LD mimics a thicker air layer despite lower u-value
Vapor Transmission Rate (g) (mg/(h-m ²))	~2870	~3509	HD lets more vapor through under test conditions

Acoustic Performance

Tests undertaken in Itecons - Construção, Energia, Ambiente e Sustentabilidade – Portuguese Subcontracted to provide certified testing

The Acoustic Performance test is performed in the laboratory at Itecons, in accordance with the ISO 10140-2:2021 standard. The normalized sound insulation curve is then determined in accordance with the ISO 10140-2:2021 standard, and the sound insulation index is determined in accordance with the ISO 717-1:2020 standard.

Acoustic chambers at Itecons were also performed according to standard .

One of the most significant outcomes of our acoustic testing was the achievement of an **airborne sound insulation rating of $R_w = 52$ dB**, obtained by combining **low-density MykoFoam panels** with a **gypsum board layer**. This result indicates **excellent sound attenuation performance**, particularly given the use of lightweight bio-based materials. The high R_w value reflects the system’s effectiveness in reducing sound transmission across a broad frequency range, making it suitable for applications requiring enhanced acoustic comfort, such as partition walls in residential or commercial buildings. The performance is especially noteworthy considering the low mass of the insulation, highlighting the potential of mycelium-based composites in high-performance, sustainable acoustic systems.

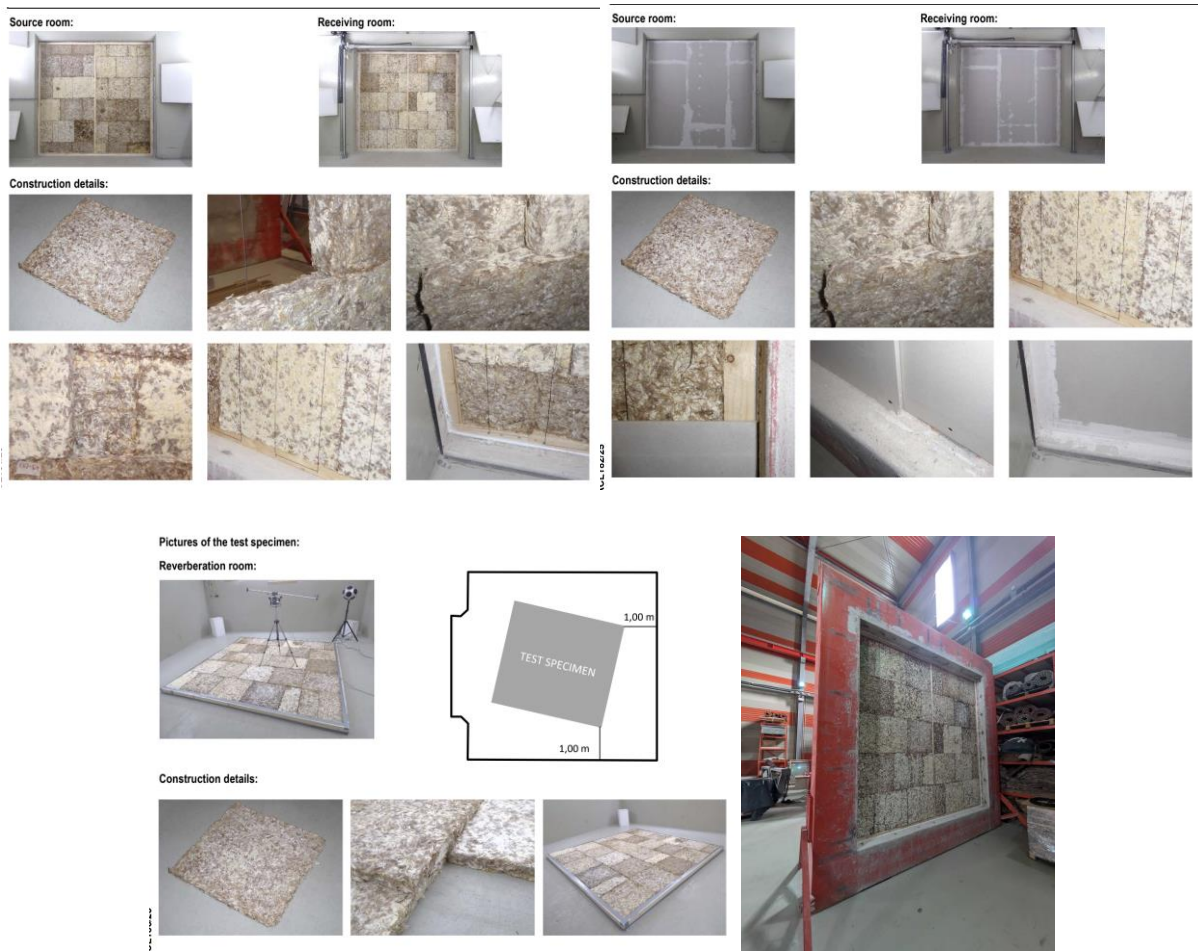


Fig 8. Acoustic tests in Itecons with exposed material on walls (top left) and gypsum board (top right); on floor (top bottom) Testing wall set up

Fire Classification

Tests undertaken in Itecons - Construção, Energia, Ambiente e Sustentabilidade – Portuguese subcontracted to provide certified testing

A **Single Burning Item (SBI) test** (EN 13823:2020+A1:2022) was carried out on three different MykoFoam samples: a high-density panel without coating, a high-density panel with a fire-retardant coating, and a low-density panel with a fire-retardant coating. This summary focuses on the **low-density coated version**, as this is the product we plan to move forward with for commercial use and the best one in terms of performance.

The fire performance of construction materials is classified based on the EN 13501-1:2018 standard. For this test, results were measured using the EN 13823:2020+A1:2022 method on a single sample. The tested sample was our **second-generation low-density panel**, which includes a fire-retardant coating. It had a **nominal thickness of 50 mm**, a **bulk density of about $60 \pm 10 \text{ kg/m}^3$** , and a **surface weight of $3,333.3 \text{ g/m}^2$** .

To prepare the sample for testing, the panels were attached to **“Gyptec BA F 13” gypsum boards** (Fig 10) using metal screws. To better simulate real-world application scenarios, we conducted testing of our product in combination with a complementary finishing material. Given that end users may choose to install our panels either exposed or covered, we selected **gypsum board**—a widely used solution in construction for wall finishing—as the cladding material. This approach provides a more representative assessment of the product’s performance in typical building assemblies and aligns with standard industry practices for interior wall construction. These boards have a **bulk density of 760 kg/m^3** , a **thickness of $12 \pm 0.5 \text{ mm}$** , and are **rated A2-s1,d0** for fire safety. During testing, the setup was placed on **calcium silicate boards** (standard EN 14306), which have a **bulk density of $870 \pm 50 \text{ kg/m}^3$** , **thickness of $12 \pm 3 \text{ mm}$** , and the same **A2-s1,d0 fire rating**.



Fig 10. LD panels with **“Gyptec BA F 13” gypsum boards**.

The test results met the required performance criteria for fire classification. Specifically, the $\text{FIGRA}_{0.4\text{MJ}}$ value was less than or equal to 250 W/s , and the total heat release over 600 seconds ($\text{THR}_{600\text{s}}$) did not exceed 15 MJ . The lateral flame spread (LFS) did not reach the edge of the specimen, and the smoke growth rate (SMOGR) remained at or below $30 \text{ m}^2/\text{s}^2$. Additionally, the total smoke production over 600 seconds ($\text{TSP}_{600\text{s}}$) was under 50 m^3 . No flaming droplets or particles were observed during the first 600 seconds of flame exposure.

This complies with the classification criteria for reaction to fire performance, as defined by **EN 13501-1:2018**, based on testing according to **EN 13823:2020+A1:2022**, and qualify the product for **Class C-s1,d0**.

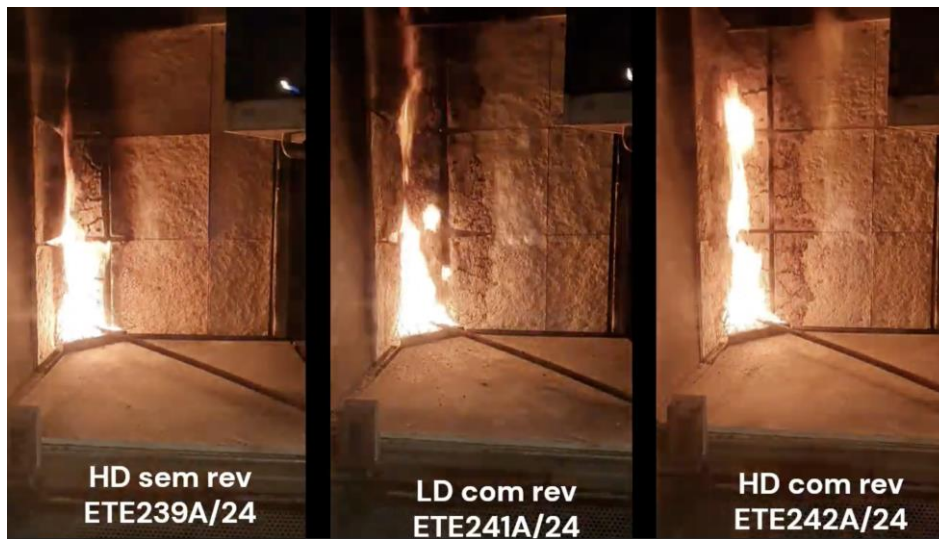


Fig 11 – Visual capture from the testing video showing all three test specimens.

3.3 Integration of product in demo buildings

In WP6, MykoFoam will be tested as insulation in **two demo sites**. In Demo Site 2 (Tiny House), 50mm boards (28m²) will be applied between reclaimed wood and the straw-clay boards as insulation material to assess insulation, breathability, moisture absorption, and durability. In Demo Site 3 (reconstruction of an old factory into a public space - Birmingham, UK), 100mm boards (180m²) will serve as the sole insulation (thermal & acoustic). Regrettably, due to limited production capacity, Mykor is unable to deliver the originally budgeted 288 m² as initially planned. The remaining allocation will instead be redirected to the Balticfloc insulation product.

Partition wall to be used is under evaluation. The aim is to achieve a **35% to 55% reduction in energy demand for renovation projects**. The newly developed #IP9 insulation will be installed in demonstration buildings that are equipped with monitoring systems to track both the thermal performance of the building envelope and indoor environmental conditions. The monitoring period will span 12 months to capture data across all seasons.

3.4 Product longevity and Environmental responsibility

We are conducting laboratory tests to evaluate the **circularity potential** of the product (WP4)—specifically, whether previously used samples can be reprocessed and reintegrated into new production cycles. For this purpose, we utilized the **LEC samples**, which serve as our most representative material due to their prior exposure to environmental chamber testing.

The experiment included four treatment conditions, incorporating both **coated** (TEOS-sol) and **uncoated** LEC samples, blended into the substrate at **10% and 60%** ratios, yielding four treatment combinations. The remaining substrate was composed of standard eucalyptus bark. Prior to autoclaving, the LEC samples were finely blended, moistened, and introduced into the growth bags following standard preparation procedures.

Following sterilisation and inoculation with 10% spent grain and 10% grain spawn, the bags were incubated in a grow tent. Remarkably, the 60% blends required only five days of incubation, while the 10% blends took seven. After this, the contents were homogenised and shaped in moulds. The 60% blends, left too long in the moulds, proved difficult to extract and should ideally have been removed by day seven. Post-moulding, samples were rewrapped and re-incubated—nine days for the 60% blends and seven for the 10% ones. Finally, all samples underwent a seven-day skinning phase, followed by drying at 40 °C.

The samples were able to be blended and added to bags to create new panels. This works for both coated and uncoated samples. The **60% samples grew faster than the 10%**; this is likely due to the presence of readily available nutrients in the form of dead hyphae and partially digested bark. These tests must be conducted at an industrial scale to evaluate their feasibility and effectiveness in a continuous, large-scale reuse process.

During Inbuilt we have targeted the following KPIs:

- **Reused material:** 50% (achieved at lab-scale)

- **Recycled material:** 100% (achieved)
- **Reusability of the products:** Test is being performed at lab-scale (expected 50%)
- **Recyclability of the products:** 60% (expected 100%)

4. #IP9 Comparison | KPIs Achieved/Expected

Comprehensive testing validated the functional properties of the bio-based insulation material across several critical areas, including: heat transfer resistance, vapour permeability, moisture interaction, acoustic dampening, and fire response. The results demonstrate that the material effectively meets the performance standards required for both thermal and acoustic insulation applications, supporting its potential for use in building envelopes.

Table 5 presents a comparison between MykoFoam and other bio-based insulation materials across several performance indicators. The evaluation demonstrates that MykoFoam is both competitive and well-aligned with market standards. While its thermal conductivity falls within an average range—outperformed slightly by sheep wool and wood fibre insulation—MykoFoam achieves a significant breakthrough in fire performance. It is the only product in the comparison to reach a Fire Reaction Classification of C, while all other assessed products remain at Class E. This notable advantage is attributed to the innovative nano-coating technology integrated into the MykoFoam manufacturing process.

Table 5. Comparison of #IP9 indicators with other competitive products

Product Type	Cellulose + mycelium	Wood fibre	Hemp insulation	Mineral Wool	Recycled polyester fibers	Wool Insulation
Product name	#IP9	Steico Flex 036	Inditherm	Knauf Dritherm 34	ISONAT flex 55	Thermafleece
Thickness mm	50-100	30-240	45-120	40-120	30-100	40-100
Density kg/m ³	60-70	50	45	75	35	18
Thermal conductivity W/mK	0.042	0.036	0.040	0.032	0.036	0.038
Reaction to fire	Class C	Class E	Class E	A1	Class E	Class E
Sound absorption (α _w)	α_w 0.9 Class A	-	A (α _w =0.95)	-	B (α _w =0.85)	-
Water vapour diffusion resistance (-)	3.1 (dry) 2.6 (wet)	2	4	-	1	1.5
Water absorption	- 0.009 ±0.002 kg/m ² s ^{0.5}	-	~0.03 kg/m ² s ^{0.5} *	1.8 kg/m ²	2.45 kg/m ²	0.99 kg/m ² h ^{0.5} .

Compressive strength kPa	1.2	-	-	-	-	-
Price @50mm £/m2 with VAT	£20	<u>£37.04</u>	<u>£17.91</u>	£16.47	<u>£12.71</u>	<u>£14.57</u>

*This water absorption value given in this table to inditherm is an average of 5 anonymised hemp insulation materials taken from a PhD thesis (Latif, 2013).

In terms of density, MykoFoam offers an average result, ranging from 60 to 70 kg/m³. Furthermore, the product exhibits strong acoustic performance, achieving a sound reduction index of $R_w = 52$ dB using a combination between our MykoFoam and gypsum. These results underscore the material's potential as a high-performance, multi-functional bio-based insulation solution.

5. Conclusions

Inbuilt has played a pivotal role in supporting Mykor across several key areas, including product characterisation and production process optimisation. Through strategic collaborations with partners, we were granted access to advanced product testing, complementary evaluations alongside other materials, and critical discussions around real-world applications —opportunities that would not have been feasible without this vital funding support.

The INBUILT project has provided a valuable opportunity to test and refine our manufacturing process, allowing us to iterate through multiple product generations in pursuit of the highest possible performance and value.

Our flagship product, **MykoFoam**—an innovative 100% bio-based insulation sheet offering strong thermal performance, inherent fire safety, and negative embodied carbon at a competitive price point—underwent comprehensive testing across multiple dimensions. During this process we have developed two generations of the same product to test which one will be better for commercial and insulation market readiness. After going through different tests, we have moved forward with LD – low density product, an improved product developed by our R&D team.

Performance assessments for **MykoFoam** encompassed a wide range of metrics, including density (measured at average **60 kg/m³**), thermal conductivity (**0.0419 W/(m·K)**), acoustic insulation (**R_w = 52 dB**), and fire safety classification (**Euroclass C**).

In parallel, the development of our second-generation, lower-density variant led to a notable increase in porosity—an outcome aligned with our design intent. This heightened internal void structure has resulted in improved water vapour permeability, enhancing the material’s breathability and reinforcing its suitability for sustainable building applications.

In pursuit of circular design principles, we also investigated **regenerative lifecycle strategies** to optimise resource use and eliminate material waste. These explorations support our commitment to a closed-loop approach to materials innovation. These tests are still progressing in the factory but at lab scale we have achieved 60% of reusability and recyclability.

Through this project, we have advanced our production capabilities by conducting targeted R&D and industrial research across various stages of the manufacturing process. As the product evolved, we recognised that while we did not achieve the target thermal conductivity of **0.038 W/(m·K)** and attained a **Euroclass C** fire classification instead of Euroclass B, these insights led us to optimise the product’s thickness. We identified that a **100mm profile** holds greater commercial viability in terms of achieving competitive U-

values. This progression has also catalysed the development of a new product line—**MykoSIP**, a **Structural Insulated Panel** that integrates MykoFoam technology and is tailored for use in prefabricated building systems.

In terms of product sustainability, the material composition reflects strong environmental credentials. The insulation is composed entirely of bio- and geo-sourced materials, a target that has already been fully met. Ongoing testing is being conducted to determine the reusability of the product, with early results suggesting a potential rate of around 50%. Recyclability is currently estimated at 60%, with further development to be done during INBUILT aiming to reach a full 100% recyclability rate.

The potential impact on energy efficiency in building renovation projects is also being explored. Although empirical data is not yet available, particularly from the demonstration site, projected energy demand reductions should range between 35% and 55%, our targeted KPIs set in the beginig of INBUILT project. These improvements reflect the product’s potential to contribute meaningfully to more sustainable construction practices.

We have reached **TRL 8**, having completed all necessary testing for pre-commercialising of our insulation panel. The next step is obtaining **CE marking**, expected by mid-to-late 2026, due to updates in the EU Construction Products Regulation.

Importantly, **third-party certified performance results** have already been secured from the accredited body responsible for our CE certification. The same tests will be used in the final CE process. The only remaining hurdle is administrative, not technical, and we are confident in securing certification.

Additionally, since our product doesn’t fit existing harmonised standards, we are developing a **custom EAD/ETA** - the most appropriate option would be to modify the existing EAD for load-bearing wood-based panels (**EAD 140022-00-0304**) - which effectively grants us proprietary rights. Any other company looking to certify a similar mycelium panel will require Mykor’s commercial approval. Our early start in this process secures this advantage.

Overall, the project is committed to enhancing all KPIs through continuous innovation in the production process, advances in surface coating technologies, and a strategic emphasis on circular economy principles. These efforts are designed to maximise both the environmental performance and the long-term viability of the product.

6. Main facts / results

The #IP9 thermal insulation material developed in this project introduces an innovative approach by repurposing waste from the paper industry as its primary raw material. Mycelium serves as a natural binder, enabling a sustainable and biodegradable composition. To enhance safety and durability, the material is finished with a nano-coating that incorporates naturally derived flame-retardant and pest-repellent agents. These additives are carefully selected to align with the product's circular design and suitability for second-life applications at the end of its use cycle.

Key Features of the #IP9 Thermal Insulation Material (as illustrated below in Fig 12):

- **Thermal Performance:** Strong insulation capability with a thermal conductivity of **0.0419 W/mK**.
- **Fire Safety:** Achieved **Euroclass C** fire resistance rating, demonstrating enhanced safety.
- **Acoustic Performance:** Excellent sound insulation, with a sound reduction index of **Rw = 52 dB**.
- **Sustainability:** Composed of **100% recycled raw materials**, supporting circular economy goals.

Ongoing Circularity Assessment (under Work Package 4, Task 4.3):

- **Direct Reuse Potential:** Up to **50%** of the material can be directly reused for insulation applications without reprocessing (validated at lab scale; factory testing pending).
- **Reusability in New Insulation:** **50%** of the product is targeted to be reusable in the production of new insulation materials (currently under lab testing, with factory trials planned).
- **Recyclability:** **60%** of the product has been successfully recycled into new insulation at this stage, with a target of **100%**, as further improvements and testing continue.



Fig 12. #IP9 Thermal Insulation Material, LD panel

7. References

1 .<https://www.sciencedirect.com/science/article/abs/pii/S0142941806000778>

2.[https://www.academia.edu/34098979/Hygrothermal Behavior of Ultra Lightweight Polystyrene Concrete?.com](https://www.academia.edu/34098979/Hygrothermal_Behavior_of_Ultra_Lightweight_Polystyrene_Concrete?.com)

EAD 140022-00-0304 - Pre-fabricated wood-based loadbearing stressed skin panels

EAD-040005-00-1201 – Thermal insulation products made of **natural fibres** (e.g., wool, hemp, flax, wood fiber, or mycelium).

EAD-040715-00-0404 – Panels for **thermal and acoustic insulation**, often used in flooring or drylining.

EN 13501-1 - Fire classification of construction products and building elements - Part 1:
Classification using data from reaction to fire tests

EN 643 - Paper and board - European list of standard grades of paper and board for recycling

EN ISO 354 - Acoustics - Measurement of sound absorption in a reverberation room

EN ISO 11654 - Acoustics - Sound absorbers for use in buildings - Rating of sound absorption

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