WP3- Improving bio-based industry in the woodworking sector

D3.2 – Report for Stakeholders: Woodworking sector-wide recommendations

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Executive summary

The ALIGNED project has provided a selection of scientifically sound methods for assessing bio-based products, which is defined within the project as the ALIGNED framework. The framework was subsequently applied to a series of case studies across five sectors, including the woodworking sector. More specifically, the woodworking case study is on wooden sheet piles and evaluates emerging hybrid and bio-modified softwood alternatives to the use of tropical hardwood. This work was conducted in ALIGNED by the partners University of Antwerp and FORECO. Based on the results and insights derived from the application to the case study, as well as based on the feedback received from stakeholders in the woodworking sector during the stakeholder involvement surveys and workshops, several recommendations were derived for stakeholders in the woodworking sector. These recommendations target the analysis of the environmental performance of wood products via Life Cycle Assessment (LCA).

It is specifically recommended to:

1) Harmonize scope, boundaries, and functional units
2) Make biogenic carbon accounting dynamic and explicit
3) Close inventory gaps on provenance, growth, and bio-based chemistry
4) Pair LCA with multi-criteria decision-making
5) Prioritize responsible material choices and decarbonize operations

Implementing these recommendations will improve comparability, reduce over- or underestimation of climate benefits, and accelerate credible scaling of wood in the built environment. The case study results indicate that hybrid designs are viable pathways to reduce tropical hardwood reliance.

The ALIGNED project results can support the implementation of these recommendations by providing guidance regarding the sharing of life-cycle data, development of foreground and background LCA models for emerging bio-based wood product technologies, carbon accounting for biogenic carbon and temporal storage, and uncertainty analysis in LCA studies of bio-based products.

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1. Overview of the sector

The European woodworking sector spans sawn wood, wood-based panels and wooden construction products, alongside pulp, paper and furniture. It employs over one million people across ~184,000 firms — predominantly SMEs, except in sawmilling and panel production where larger enterprises prevail (European Commission, 2023). The industry depends on Europe's expanding forests: about 40% of EU land is forested, reaching ~159 million ha in 2020, 10% more than in 1990 (Eurostat, 2021, 2023 & 2024). and grows by nearly 700,000 ha annually.

Wood is inherently bio-based and typically has a smaller carbon footprint than many substitutes because processing is less energy-intensive and wood stores biogenic carbon (Rinne et al., 2022). Environmental issues remain critical: poor management and illegal logging damage biodiversity and heighten erosion, drought and wildfire risks. EU measures such as FLEGT and the EUTR, alongside stewardship programs, address these pressures (European Commission, 2023). When paired with sustainable forest management, growing demand for wood products can expand forest area and CO_2 capture, supporting climate-change mitigation (Iordan et al., 2018).

Roughly half of harvested wood becomes saw and veneer logs, which are processed into solid timber (planks, beams, posts) and engineered wood products (EWPs) with consistent performance for construction—e.g., glulam, CLT, LVL, plywood, OSB, MDF and PSL. EWPs are manufactured from fibres/particles with binders into boards that can be cut and sawn like timber (European Commission, 2023; Sandberg, 2016). Cascading use is common: mill residues and non-veneerable fractions feed composites or fuelwood, improving resource efficiency (Sandberg, 2017).

Additives are pivotal to deepening the sector's bio-based profile. Woodworking is the world's largest adhesives user; ~80% of products need them, yet only ~9% of EU adhesive output is bio-based and many conventional systems are formaldehyde-based (Sandberg, 2016; Spekreijse et al., 2019). Viable bio-based alternatives include collagen, dairy/gluten proteins, starch, cellulose and lignin (Ülker, 2016). Fossil-based preservatives — some now restricted, such as CCA, pentachlorophenol and creosote — are increasingly complemented by bio-based coatings (waxes, shellac, drying oils) and wood-modification routes like furfurylation (from agricultural residues) and thermal treatment with vegetable oils (Western Wood Preservers Institute, 2023; van Dam & van den Oever, 2019). Sustainability assurance relies on FSC and PEFC certification, while life-cycle assessment compares species mixes and bonding choices (Michal et al., 2019).

The woodworking case study in ALIGNED focused on wooden sheet piles in "ground, road, and water" applications, where tropical hardwoods are common for durability and resistance but raise concerns around biodiversity, certification integrity, long growth cycles, transport, and associated emissions. The case evaluates three improvement pathways that maintain performance while reducing environmental impacts and dependence on tropical hardwoods: (i) a hybrid design combining softwood with limited high-durability hardwood components (TwinWood), (ii) bio-modified softwood (FaunaWood) using resins derived from wood residues and plant waste (bagasse) and (iii) a combination of both using FaunaWood for durability (Foreco, 2025; Sahoo, 2019).

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2. Identified sustainability assessment challenges

2.1. Main environmental challenges associated with the sector

Woodworking spans forest management, harvest, processing, use, and end-of-life. Its impact reflects biogenic carbon flows (uptake, storage in long-lived products, and end-of-life release), energy and material use during processing, chemical inputs (e.g., adhesives and finishes), transport across globalized supply chains, and waste management. The sector can replace higher-carbon materials in buildings, but actual benefits depend on what is substituted and market response. Biodiversity losses, deforestation, forest degradation and the toxicity of wood modification chemicals were identified as most important environmental impacts by stakeholders.

2.2. Challenges which are not properly addressed

Inconsistent scope and functional units undermine comparability of LCAs. Current LCAs vary widely in system boundaries and functional units, with cradle-to-gate still dominant and only a small share adopting cradle-to-cradle perspectives. Even where 1 m² is used (often in construction), lifetimes and service contexts differ. This heterogeneity prevents robust benchmarking and technology evaluation, weakening both policy design and procurement decisions (Van den Auwelant et al., 2025).

Fragmented standards and LCIA methods lead to conflicting results. EPDs, PCRs, and PEFs aim at transparency, yet incompatibilities among PEF, EN 16485 & EN 15804, and wood-specific EPD rules persist, and studies mix methods (e.g., ReCiPe, CML, TRACI) without clear justification. As endpoints (e.g., ecosystem quality, resource depletion) are highly relevant to forestry products, the frequent omission or inconsistent treatment of endpoint indicators distorts trade-offs and hampers reproducibility (Minkov et al., 2020; Bach et al., 2018; Durão et al., 2020). This erodes trust and enables selective reporting.

Attributional LCA misses market-mediated effects and substitution realities. Most assessments are attributional, which cannot capture how increased timber demand alters harvest regimes, global trade, or the degree to which mass timber displaces steel or concrete and wood co-products (wooden debris, sawmill chips and sawdust, used as fuels, soil coverage, or for wooden panels such as OSB, fibreboards, etc.). Consequential LCA is more prevalent in this sector than elsewhere but remains underused and inconsistently applied. Without guidance on marginal suppliers, displacement factors, and indirect land-use change, studies risk over- or underestimating climate benefits, leading to misguided scaling or policy incentives (Mathiesen et al., 2009; Cordier et al., 2022; Howard et al., 2021).

Biogenic carbon is handled statically. ISO acknowledges biogenic carbon but does not prescribe how to treat storage duration, release timing, or regrowth. Static approaches ignore that time to ecosystem carbon neutrality varies widely by species and location (on the order of decades), and that outcomes hinge more on temporal modelling choices than on the impact method itself. End-of-life pathways, landfilling versus incineration with/without energy recovery, govern when stored carbon is returned to the atmosphere. Without dynamic, sector-specific protocols, LCAs can misinform forest planning, product design, and claims about “carbon-neutral” wood (Head et al., 2019–2021; Garcia et al., 2020).

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Inventory gaps hide promising low impact materials. Innovative bio-based adhesives (e.g., soy- or tannin-based) often have better environmental profiles than fossil alternatives but are poorly represented in mainstream LCI datasets. Similarly, forest growth and management data remain scattered across emerging resources (e.g., EFO-LCI, MODIS-based NPP), limiting consistent modelling of regional forestry practices. These gaps bias results toward incumbent materials and reduce the visibility of improvement options (Arias et al., 2020; Cardellini et al., 2018; Neumann et al., 2016).

Limited integration of broader sustainability metrics. Environmental LCAs are seldom combined with economic and social dimensions, and decision tools such as multi-criteria decision making are not yet mainstreamed for wood products. As a result, choices may optimize a single environmental indicator while neglecting feasibility, costs, jobs, or land-use conflicts—weakening real-world uptake and policy coherence (Van Schoubroeck et al., 2021; Balasbaneh et al., 2021).

Together, these gaps create non-comparable results, overconfident climate claims, and a tendency to underestimate the environmental benefits and risks of wood products. Consequently, they slow down standardization and can misguide investments.

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3. Recommendations

This section translates the issues identified in Sections 1–2 into practical, sector-ready actions. It prioritizes steps that companies and consultants can implement immediately.

3.1. Harmonize scope, boundaries, and functional units

Non-comparable LCAs arise from mixed system boundaries (often cradle-to-gate), inconsistent functional units, and unstated/variable lifetimes. Therefore, we recommend to:

- Adopt **cradle-to-grave as** the default scope for product LCAs and apply cradle-to-cradle where relevant for reuse, recycling, or energy recovery. For this we also refer to the ALIGNED framework on LCIA (Hamelin, Javourez & Arbault, 2025).
- Use a **sector functional unit (FU)** pack for common applications (e.g., 1 m^2 sheet pile over a declared service life; 1 m^3 structural element) with **explicit reference service life (RSL)** and context of use.
- Publish a one-page **method sheet** with every study (goal/scope, FU, lifetime, data vintages, cut-offs) to enable comparability.
- For **portfolios with many variants** to:
    - **Maintain parametric models** so the FU, lifetime, and key levers (origin, energy mix, EoL) can be switched without rebuilding the study.
    - Handle multi-output processes as interlinked and apply system modelling (cut-off, Allocation at the Point of Substitution (APOS), or consequential) to **allocate or substitute burdens as late as possible**. This ensures flexibility, comparability, and avoids locking results into one interpretation too early.

3.2. Make biogenic carbon accounting dynamic and explicit

Static treatment of biogenic carbon obscures timing of uptake, storage, and release, while EoL pathways drive real outcomes. Based on the outcomes of the woodworking case study, the ALIGNED project recommends to:

- Apply **dynamic biogenic carbon accounting** using ALIGNED guidelines (Hamelin, Javourez & Arbault, 2025) alongside the static view; report time-profiles of removals and emissions.
- Disaggregate climate results into **fossil, biogenic, and land-use** components; report **GWP100 and GWP500** for short-term and long-term climate effects.
- Use a **minimum EoL scenario set** with realistic yields and timing (direct reuse → refurbishment → material recycling → energy recovery) and include storage duration where relevant.
- **Credit storage only when verifiably achieved** (documented reuse or long-term storage) and accompany any interim negative values with a disclaimer about EoL dependence (e.g., the benefit is conditional and can be reversed when the product is incinerated or otherwise releases the stored carbon).

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3.3. Close inventory gaps on provenance, growth, and bio-based chemistry

Missing or generic LCIs hide low-impact options and weaken biodiversity/carbon credibility. To overcome these gaps, we recommend to:

- Use a **structured sector LCI template as the the ALIGNED LCI data template** (Pizzol, Ghose, & Lancz, 2024) to collect and share data;
- Improve reproducibility by **adding relevant metadata** capturing e.g., species, geotagged origin and management regime, age class, moisture, treatment type, energy carriers, transport modes/distances, by-product fates, and intended EoL.
- Integrate **species- and region-specific growth models** (e.g. ALIGNED carbon flux model for a forest plantation by Lancz, Nørgaard Bollesen & Pizzol (2024))**,** into foreground models, document data gaps and apply **tiered modelling** (use dynamic modules when available, conservative static proxies otherwise).
- Record **uncertainty and sensitivity** for e.g., origin, growth rate, and adhesive system to prevent misinterpretation of robustness and report ranges.

3.4. Pair LCA with multi-criteria decision-making

Environmental LCAs are not integrated with economic/social metrics and constraints, while decisions typically optimize a single indicator. From ALIGNED, we recommend to:

- Use **multi-criteria decision making** and the ALIGNED framework for socio-economic assessment (Tschulkow, 2025) to weigh climate, cost, durability, biodiversity and social risk (e.g., due diligence exposure).
- Identify risks when scaling specific wood products by using the method for modelling **constraints to biomass availability** (Pizzol, Ghose, & Nørgaard Bollesen, K. (2024)).

3.5. Prioritize responsible material choices and decarbonize operations

Tropical hardwood reliance, transport intensity, and fossil-heavy processing remain hotspots for the woodworking sector. From the LCA results for the woodworking case study we recommend to:

- Default to **modified softwood, followed by hybrid designs** (combining tropical hardwood with (modified) softwood) **or local alternatives** where technically feasible.
- **Switch to renewable electricity and electrify** kilns, presses and transport.

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4. Conclusions

The European woodworking sector holds substantial potential to contribute to climate mitigation and circular economy objectives. Realizing this potential depends on demonstrably sustainable forest management, credible material substitution in specific use contexts, temporally explicit treatment of biogenic carbon, and end-of-life pathways that are feasible in practice. If these conditions aren't met, the benefits claimed are likely overstated or not reproducible.

Current LCAs of wood products are undermined by inconsistent system boundaries, fragmented standards, and heterogeneous methods, which prevent comparability and weaken both procurement and policy design. Attributional approaches dominate but fail to capture market-mediated effects or realistic substitution, while static treatment of biogenic carbon obscures the timing of uptake, storage, and release that is critical for forestry-based products. Large inventory gaps, particularly for growth models, provenance data, and innovative bio-based adhesives, further bias results toward incumbents. The limited integration of broader sustainability metrics compounds these issues, creating non-comparable outcomes, inflated climate claims, and an underestimation of both benefits and risks. Collectively, these weaknesses slow standardization, reduce trust, and risk misdirecting investments in the sector.

In light of the above, we recommend to:

1) Harmonize scope, boundaries, and functional units.
2) Make biogenic carbon accounting dynamic and explicit.
3) Close inventory gaps on provenance, growth, and bio-based chemistry.
4) Pair LCA with multi-criteria decision-making.
5) Prioritize responsible material choices and decarbonize operations.

By implementing these recommendations, the woodworking sector can improve the comparability and robustness of its environmental assessments, strengthen claims, and support viable scaling of wood-based solutions.

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