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WP2- Improving bio-based industry in the construction sector

Deliverable D2.2: Report for Stakeholders: Construction sector-wide recommendations

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Executive summary

The ALIGNED project has provided a selection of scientifically sound methods for assessing the environmental performance of biobased 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 construction sector. More specifically, the construction case study is related to an insulating board made of phenolic foam, relying on emerging technologies to produce bio-based phenol from lignocellulosic biomass. This work was conducted in ALIGNED by the partners KINGSPAN and INSAT. Based on the results and insights derived from the application of the ALIGNED framework to the case study, as well as based on the feedback received from stakeholders in the construction sector during the stakeholder involvement surveys and workshops, several recommendations were derived for stakeholders in the construction sector. These recommendations target the analysis of the environmental performance of biobased products via Life Cycle Assessment (LCA) and are the object of ALIGNED project's Deliverable 2.2.

It is specifically recommended to: 1) Ensure high-quality and standardized data collection across the value chain, 2) Promote harmonization between standards, scientific soundness and methodological alignment, 3) Avoid allocation methods among bio-based co-products and prefer system expansion, 4) Promote the use of biomass for durable, long-lived products, preferably substituting fossil or mineral products, 5) keep clear carbon flow tracking and advanced climate change impact assessment metrics, in order to shed light on the environmental advantage of long-term carbon storage, 6) consider contrasted scenarios for the end-of-life phase for used products.

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 biobased technologies, carbon accounting for biogenic carbon and temporal storage, and uncertainty analysis in LCA studies of biobased products.

1 Overview of the sector

A detailed overview of the bio-based construction sector in Europe is available in earlier ALIGNED work (Groenestege et al. 2023) and is summarized herein.
The construction sector provides the buildings and infrastructure needed by the rest of the economy and society. This includes the extraction of materials, the manufacturing and distribution of construction products as well as the design, construction and management of construction works.

The construction sector is the EU's leading industrial employer. The sector directly employs about 19.8 million people, which is about 4.4% of the total EU population. Additionally, with a turnover of 2.66 trillion euros in 2020, the construction sector contributes to roughly 9% of the EU's GDP (ECSO 2023).

There are two key functions where biobased materials enter the construction sector, namely structure and insulation. The former is dominated by wood. Wood in fact accounts for 1.6%wt of materials used in the overall EU construction sector, averaging at 24.8 million tonnes per year between 2006 and 2010 (Herczeg et al. 2014). While wood has traditionally been used in construction for many years in certain regions of the world, new load-bearing elements have

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led to the increasing popularity of using wood in construction. Engineered wood products (EWP) can be divided into three categories: wooden panels (including plywood, medium and high-density fibreboards, particle boards, oriented strand boards), mass timber products (e.g., cross-laminated timber (CLT), glue-laminated timber) and structural composite lumber products (e.g., laminated veneer lumber, parallel strand lumber). EWP production and use is steadily increasing globally, with a CAGR around 4.9% (IMARC 2025). CLT is claimed to have similar strength to concrete and steel, making it a great alternative in larger and taller constructions (Hetemäki et al. 2017). Rigid fibreboards and oriented strand boards also have interesting mechanical properties that may make them preferred to plasterboards.

For insulation, there are various bio-based alternatives to mineral wools and fossil-based plastic foams, which include wood fibres, plant fibres, cork, mycelium, cane, and rice and coconut husks. The bio-based insulation market has grown by 40% in the last three years and is estimated to have a market share of 10% of current insulation materials production (Lecompte and Picandet 2022). On the German market, for instance, fossil-based insulation materials currently have a market share of 48% and mineral-based insulation materials 45% of all insulation materials. The other 7% is bio-based insulation materials, of which most comes from wood fibres (51%) and cellulose (41%); with small contributions from hemp (5%) and other biomass sources (2%) (Schulte et al. 2021).

The selected case study for ALIGNED is Kingspan's Kooltherm K5 external wall insulation board. The product is essentially composed of a rigid, thermoset phenolic foam faced on both sides with a glass tissue-based facing. Previous internal Life Cycle Assessment (LCA) studies reported that petrochemical phenol is the main contributor to most environmental impact categories. During the ALIGNED project, two promising technologies for 100% bio-based phenol production were investigated. We believe that this case study provides an insightful example for companies willing to directly substitute fossil-based chemicals by bio-based ones (so-called 'drop-in' situations).

2 Identified sustainability assessment challenges

2.1 Main environmental challenges associated with the sector

Due to its great size and important need for material resources, the construction sector faces some major environmental impacts. According to the European Commission (ECSO 2023), the construction sector is one of the largest consumers of resources in the European Union (EU), as it consumes about 50% of the materials extracted in the EU. Buildings account for 40% of the total energy consumption and 36% of energy-related emissions in the sector, mostly coming from the usage of buildings. The construction and renovation of buildings is, in EU countries, estimated to contribute to about 5-12% of total national Greenhouse Gas (GHG) emissions (ECSO 2023). The construction sector also accounts for around one-third of the EU's freshwater consumption and the construction and demolition of buildings and infrastructure generate a lot of waste, accounting for over one-third of the EU's total waste generated (Pozzi 2022).

Global warming, resource depletion, energy use and waste management were in fact the most mentioned among environmental priorities by participants from construction sector to (i) the first ALIGNED online workshop on the construction sector (Figure 1), and (ii) the open online consultation (Figure 2) (Reumerman 2023).

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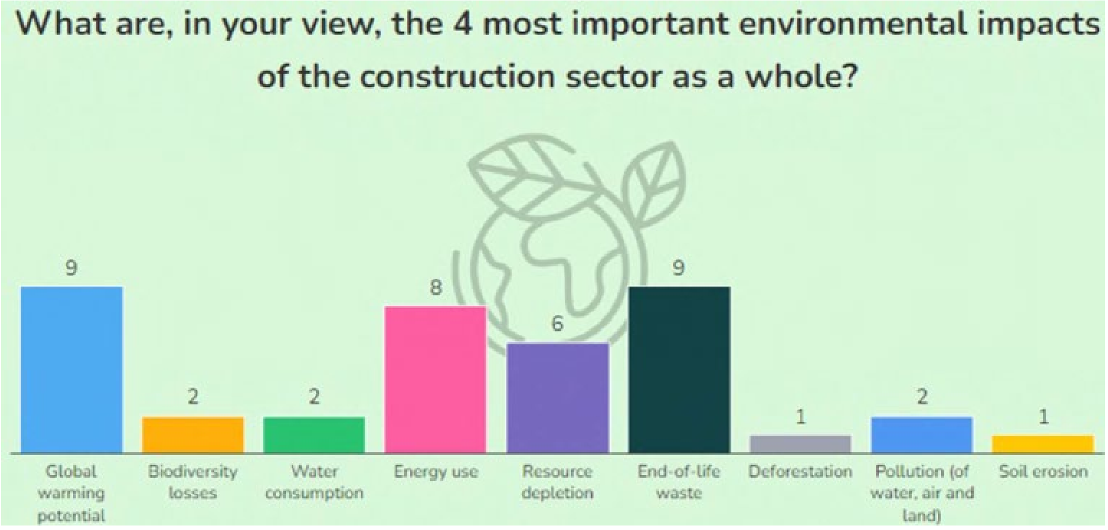

Figure 1: Stakeholders' opinions on the most important environmental impacts for the construction sector. Values indicate the number of votes during ALIGNED online sectorial workshop on March 2023 (max 4 votes per person).

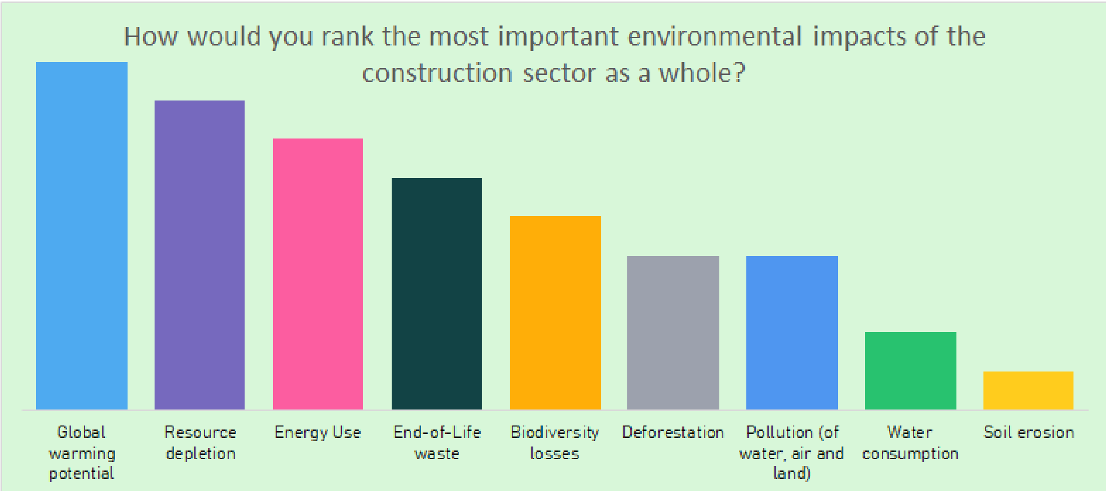

Figure 2: Stakeholders' opinion on environmental issues for the construction sector. Tallest bars show the most important environmental impacts according to results from online consultation open in January and February 2023.

Many national certification schemes for the environmental performance of buildings and materials help industries in sharing and improving best practices. For example, most standards agree on encouraging building with wood, as it uses a relatively small amount of energy to produce, is relatively easy to reuse, and captures CO_2 during growth.

2.2 Challenges which are not properly addressed

As compared to other sectors, practitioners, industries and policy makers are quite well equipped with tools for environmental accounting such as Environmental Product Declaration (EPDs), existing background database, certification and standards. It was made very clear at the second ALIGNED sectorial stakeholders' consultation (held between May and June 2025; Reumerman et al. 2025) that the construction sector relies heavily on EPDs. Indeed, the EPD scheme was reported as the result of decades-long consensus work, stated to be generally well detailed and harmonized while easy to generate and read, thus enabling comparability among products. Under the 2024 published Construction Products Regulation (CPR),

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construction products will need to include environmental impacts in their 'CE' marking (Regulation 2024/3110). The LCA methodology will then become a mandatory part of product declarations, following strict guidance from standards. This will replace the current way of working with voluntary EPD schemes in construction. The new regulation will gradually become applicable to the different type of construction products. It starts with a mandatory inclusion of the Global Warming Potential (GWP) and will be followed shortly by the other environmental indicators according to EN 15804.

In contrast, stakeholders from research institutions voiced that several environmental assessment challenges may induce biases grounded in the underlying normative choices inherent to any standard (De Rosa et al. 2018; Hoxha et al. 2020; Pawelzik et al. 2013). Konradsen et al (2024). For example, EPDs deliver information on how the product *has been* manufactured, but EPD results are frequently used by manufacturers as standalone information for decision-making on *future* eco-designed production processes. Environmental accounting and environmental strategy clearly have diverging goals and scopes, and thus should follow different LCA frameworks (see e.g. Pawelzik et al. 2013, section 5; Zamagni et al. 2012).The main reason from this bias in LCA practice seems to stem from a lack of expertise on consequential LCA, as expressed by consulted stakeholders . Yet, when a company seeks phasing out its reliance on stock-limited (fossil) feedstocks and moving towards flow-limited (renewable) resources, it is of utmost importance to adopt a consequential mindset (Ekvall and Weidema 2004): since biomass is flow-limited, increasing the demand for a specific bio-based resource necessarily triggers cascading effects on other markets (e.g. an increase in the offer of the co-products) or actors (e.g. other activities that rely on the same bio-based resource).

In addition, consulted stakeholders expressed a keen interest in a framework for time-explicit climate impact assessment, especially to make explicit the effects of temporary carbon storage in biogenic resources and products. This topic is frequently explored by the scientific community (Navare et al. 2022; De Rosa et al. 2018; Andersen et al. 2021; Ouellet-Plamondon et al. 2023; Pawelzik et al. 2013; Hoxha et al. 2020). Most conclude that dynamic or time-explicit carbon accounting is preferable. Yet, consulted practitioners also refrained from investing time and training on time-explicit GHG accounting, because this aspect is not explicitly required by existing standards.

A limited interest in uncertainty assessment and sensitivity analysis tools was also highlighted, even though it is an inherent part of the interpretation step and to formulate balanced recommendations to decision-makers.

3 Recommendations

3.1 Recommended methodological approaches to LCA

When setting system boundaries, it is recommended to:

Use system expansion and avoid allocation. Include the full fate of co-products (from joint production) in the system boundaries, from use to eventual products substituted. Cf. ALIGNED case study on the construction sector for a comprehensive example. Consider biomass re-growth as occurring *after* harvest, for consistency with decision-making. Consider biomass as a flow-limited resource: Identify whether constrained supplies are involved, using T1.2

guideline ‘constraints to biomass availability’1. Include indirect land-use change whenever additional land is needed. Apply cradle-to-grave boundaries and include contrasted end-of-life scenarios if the current end of life is unknown.

In the Life Cycle Inventory phase it is recommended to: Adopt FAIR principles for data sharing. Using yhr ALIGNED LCI data template2can support this. Adopt dynamic modelling for a time-explicit approach of biogenic CO2 uptake and release3. Give priority on seeking primary data from suppliers, or on process-specific data from reliable sources.

In the Life cycle impact assessment (LCIA) it is recommended to:

Consider the -1/+1 approach4 and track biogenic carbon flows with mass balance.

In LCA software, make sure to ensure consistency between the LCIA methodology selected and the exact flows reported from the LCI. For example, the flow ‘carbon dioxide, biogenic’ is not associated with a characterization factor in the EF method. Particular awareness needs to be paid for flows where ‘fossil/non-fossil/biogenic’ options can be selected.

For a quick and accessible estimation on the importance of time dimension in GHG footprinting, use Tier 1 tool of ALIGNED time-explicit impact assessment framework5. This is recommended in particular when dealing with durable products and/or slowly renewable biomass.

When interpretating LCA results, it is recommended to: double-check assumptions of underlying background modelling when significant impacts stem from background processes. Include at minimum Tier 1 recommendations of ALIGNED guideline for uncertainty / sensitivity analysis prior to formulating conclusions and follow-up decisions6.

3.2 Recommendations to producers (takeaways from case study)

For woody biomass production it is recommended to invest in long-term partnerships with forestry activities to secure environmentally performant feedstock production at supply level (i.e. in m3 wood, not ha land) and anticipate adaptation of forestry to climate change.

It is recommended to promote use of biorefineries’ co-products which directly contributes to phasing out reliance on fossil resources and support EU environmental policies towards 1) GHG mitigation and 2) carbon sequestration. For example, whenever possible, co-products should be targeted to obtaining higher-value compounds able to substitute fossil- and mineral-based products (e.g., polymer or mineral insulating products) able to store biogenic carbon for the longest periods. Otherwise, co-products should be targeted to energetic applications able to substitute fossil fuels.

[1] https://zenodo.org/records/10843454
[2] https://zenodo.org/records/10843472
[3] https://zenodo.org/records/10843343
[4] See ‘Guide on the Life Cycle Impact Assessment (LCIA) for bio-based products – Climate change'. https://zenodo.org/records/11126481
[5] See ‘Tutorial on including time-dependencies in the estimation of climate change midpoint scores of bio-based productions – Tier 1'. https://zenodo.org/records/11126481
[6] https://zenodo.org/records/10842720

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3.3 Recommendations for policy makers

Adopting a bio and circular economy requires a paradigm shift: *flows*, rather than *stocks*, shall be considered as the limiting factor of material extraction. 'Bio-circular' economic growth cannot be measured by the volume of material goods production, because the extraction rate of a renewable resource is capped by the renewal rate of that resource.

It is recommended to enhance Life Cycle Thinking principles for environmental management to include market mechanisms and complex production systems into an integrated approach for decision-making and strategic planning.

Firmly defend the environmental objective of 'phasing out dependence of fossil fuels', in order to stir investors and business developers in biorefineries and renewable energies.

Whenever possible, support energy *decarbonation* rather than *defossilisation* to avoid short-term biogenic CO_2 release. As mentioned in section 3.2, policies should target 1) GHG mitigation and 2) carbon sequestration.

4 Conclusion

The construction sector is one of the largest consumers of material resources. In addition, manufactured products for construction are intended to be in use for a very long period. Over the last century. the sector has been widely relying on mineral materials and energy-intensive products. But in the last decades, the demand for biobased products steadily increases among estate owners and construction companies.

The enhanced ALIGNED framework for LCA of bio-based products sheds light on the key role of industrial sectors able to massively uptake CO_2 and to store them in long-lived products. To this end, the construction sector is expected to play a role of primary importance in global climate strategy.

As illustrated in the case study, products manufacturers invest in research and development for new bio-based, technological products able to substitute fossil-based and mineral ones with as little adaptation as possible by the supply chain and products users. The case study shows to which extent innovative technologies can participate in substituting key chemicals for specialized construction products, contributing to GHG mitigation and carbon sequestration – provided biomass regrowth is guaranteed, and co-products are handled in a way consistent with these climate strategies. Other ALIGNED case studies are complementary examples on the role of bioeconomy sectors in climate strategies.

Nevertheless, using biomass feedstock raises new challenges, such as increased demand for land, stress on flow-limited biomass availability, prioritization of co-products use (towards long-term, high-value material products). Consistent environmental accounting standards need to encompass the specificity of biomass resources to avoid adverse effects from biomass exploitation.

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