DEVELOPMENT AND PILOT PRODUCTION OF SUSTAINABLE BIO-BINDER SYSTEMS FOR WOOD-BASED PANELS

Deliverable 5.2 - Summary

LCA of proposed feedstock

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Lead beneficiary:	CE Delft
Main contact:	Sanne Nusselder, Nusselder@ce.nl
Other contributors	Ingrid Odegard, Martijn Broeren

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Publishable summary

The SUSBIND project

The SUSBIND consortium develops, produces and tests bio-based adhesive systems as an alternative to adhesive systems based on a formaldehyde resin as currently used for wood-based panel boards in furniture mass production. SUSBIND aims at producing these bio-based adhesive systems with leading wood board manufacturers for two product types: P2 particleboard (PB) and medium density fibreboard (MDF). The resulting bio-based adhesive system aims to outperform current conventional adhesive systems by means of a significantly lower carbon footprint, while also reducing emissions toxic to humans.

This study

This life cycle assessment (LCA) supports the ongoing SUSBIND project by evaluating the carbon footprint of different feedstock options that are under consideration for the development of a (partly) bio-based adhesive system for P2 PB and MDF. By assessing the carbon footprint of four different carbohydrate/oil feedstock options, this report identifies those options that are most likely to achieve SUSBIND's carbon footprint reduction target. The four adhesive systems that are studied are:

1. **Adhesive 1 - Carbohydrate feedstock:** A carbohydrate feedstock is used instead of formaldehyde (methanol) in the resin production. The expected resin recipe furthermore has a lower urea content than the UF-resin as used in state-of-the-art production of PB and MDF. All other aspects of adhesive formulation and board production are unchanged.
2. **Adhesive 2 - Combination of carbohydrate and oil feedstock in resin:** A combination of carbohydrate and oil feedstocks together replace the conventional resin. All other aspects of adhesive formulation and board production are unchanged.
3. **Adhesive 3 - Combination of carbohydrate and oil feedstock in adhesive:** The carbohydrate is used instead of the formaldehyde (methanol) and the epoxidised oil from oil feedstock is used instead of the conventional hydrophobic agent. The foreseen resin recipe furthermore has a lower urea content than the UF-resin as used in state-of-the-art production of PB and MDF. All other aspects of adhesive formulation and board production are unchanged.
4. **Adhesive 4 - Oil feedstock**: An oil feedstock is used to produce epoxidised oil that replaces the entire resin. All other aspects of adhesive formulation and board production are unchanged.

For carbohydrate feedstocks, production from wheat and maize grain is studied. For oil feedstocks, production from linseed, rapeseed, soybean and sunflower is considered.

Function and functional unit

The SUSBIND consortium aims to develop an adhesive system for two types of board products, particle board (PB) of Type P2 and medium density fibreboard (MDF). For each of these boards a functional unit is defined:

- Functional unit for PB: An adhesive system for P2 PB measuring 450 by 550 by 14 mm, meeting the performance requirements.
- Functional unit for MDF: An adhesive system for MDF measuring 450 by 550 by 12 mm, meeting the performance requirements.

'Adhesive system' is defined in this assessment as all components of the board which are not wood. This includes the resin and any additives which contribute to attaining the functional requirements. The assumption behind this definition is that the wood use (type and quantity) will not change when switching from conventional to a bio-based adhesive. The energy use required to produce the board (to press resin and wood chips together etc.), as well as wood production and (pre)treatment is outside the scope of this analysis, with the assumption that switching from conventional to bio-based adhesive will not influence this

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energy use. For end-of-life, incineration without energy recovery is assumed. These assumptions will be checked later in the SUSBIND project.

Analysis

This LCA focuses on the production of different feedstocks. The focus is therefore on raw material production (i.e. crop cultivation) and the conversion into a feedstock that can be used for resin production, i.e. carbohydrates such as glucose or refined oils from vegetable oil crops. This means that subsequent steps such as the processing into a resin and adhesive are not yet accounted for in detail (these will be addressed in the next deliverables once the project moves forward). The amount of feedstock required to fulfil the functional unit is therefore a first estimation based on the project's initial process scheme.

Based on the amount of feedstock required, we determine the carbon footprint of the four adhesive systems, used in both PB and in MDF. This accounts for all emissions, resource extractions, forms of energy use, and co-products generated in the production process. Both primary data from consortium data and publicly available background data is used to construct the models.

The carbon footprint results for the different feedstocks are compared to the lowest likely carbon footprint for state-of-the-art petrochemical adhesive systems for P2 PB and MDF. One of SUSBIND's goals is to develop (partly) bio-based adhesive systems with a carbon footprint that is at least 5% lower than the conventional petrochemical adhesives. In Deliverable 5.1, these carbon footprints for the petrochemical adhesive systems were established as:

- 490 gram CO_2 eq. for P2 particleboard measuring 450 by 550 by 14 mm;
- 650 gram CO_2 eq. for MDF measuring 450 by 550 by 12 mm.

Land use represents a particular concern for bio-based products, for instance due to the greenhouse gas emissions that can occur when natural land is converted into cropland. Separately from the carbon footprint, we therefore estimate the amount of land that the adhesive systems would require, assuming that the entire EU's consumption of PB and MDF would use the new (partly) bio-based adhesive systems. In addition, we estimate the associated greenhouse gas emissions from the associated land use change, using the Direct Land Use Change Tool developed by Blonk Consultants.

Carbon footprint (excluding land use change impact)

Below, Figure 1 and Figure 2 show the default results for P2 PB and MDF, respectively. Please note that these results do not include the climate change impact of direct land use change (estimated separately). When using oil feedstocks, the black error bar shows the difference in environmental footprint between the four types of potential oil feedstocks.

When using adhesive system 1 (carbohydrates) for particleboard, a 28% carbon footprint reduction can be achieved. The highest reduction of carbon footprint can be achieved by using an epoxidised oil made from soybean oil as resin in adhesive system 4 (65% reduction). It is however not yet clear whether this is technically feasible. Combining an oil and a carbohydrate feedstock (using the epoxidised oil as wax replacement) could lead to a carbon footprint reduction of at most 32% (adhesive 3) in comparison to state-of-the-art P2 PB production based on petrochemical ingredients, and combining the two types of feedstock in a resin can lead to a carbon footprint reduction of at most 59% (adhesive 2).

For MDF, Figure 2 shows that a carbon footprint reduction of 15% is possible when using a carbohydrate feedstock as in Adhesive 1. The highest carbon footprint reduction can be achieved by using an epoxidised oil from soybean oil as resin, corresponding to Adhesive system 4 (68% reduction). It is however yet unclear if this is technically feasible. Combining an oil and a carbohydrate feedstock (using the epoxidised oil as wax replacement) could lead to a carbon footprint reduction of maximum 41% in comparison to state-of-the-art MDF production based on petrochemical ingredients (Adhesive 3), and combining the two types of feedstock in a resin can lead to a carbon footprint reduction of maximum 32% (Adhesive 2).

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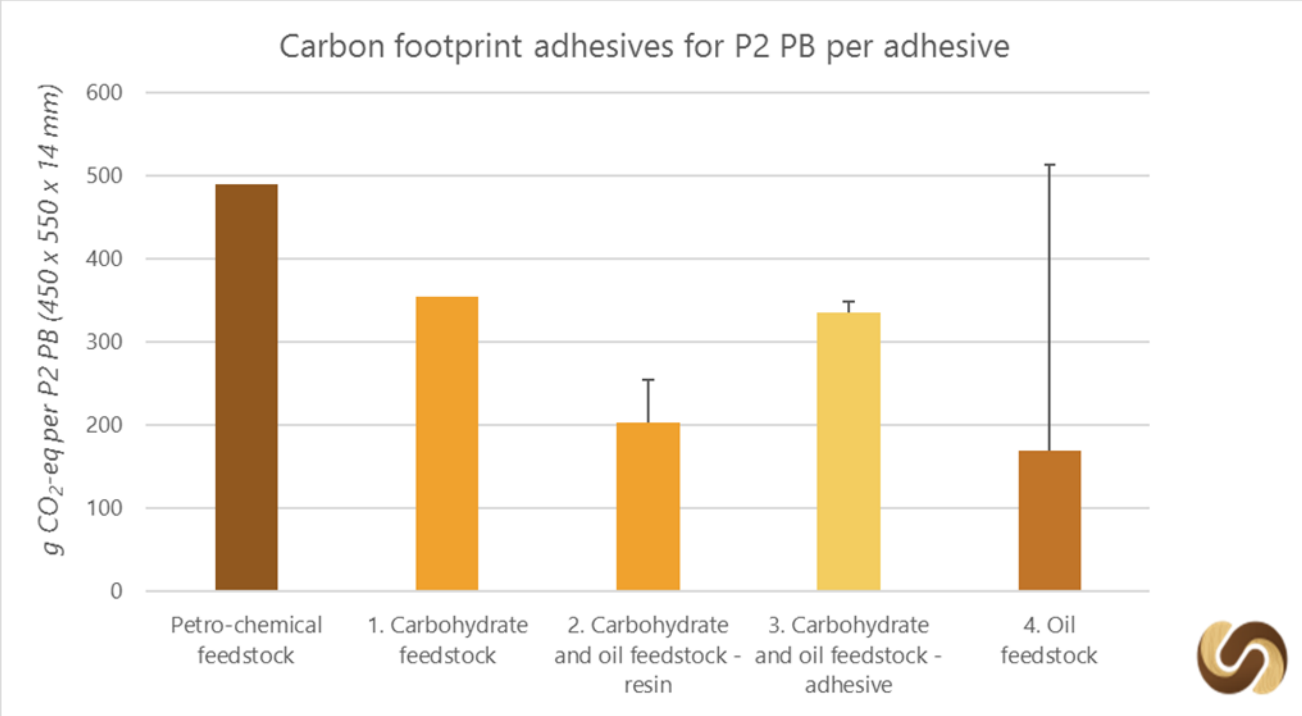
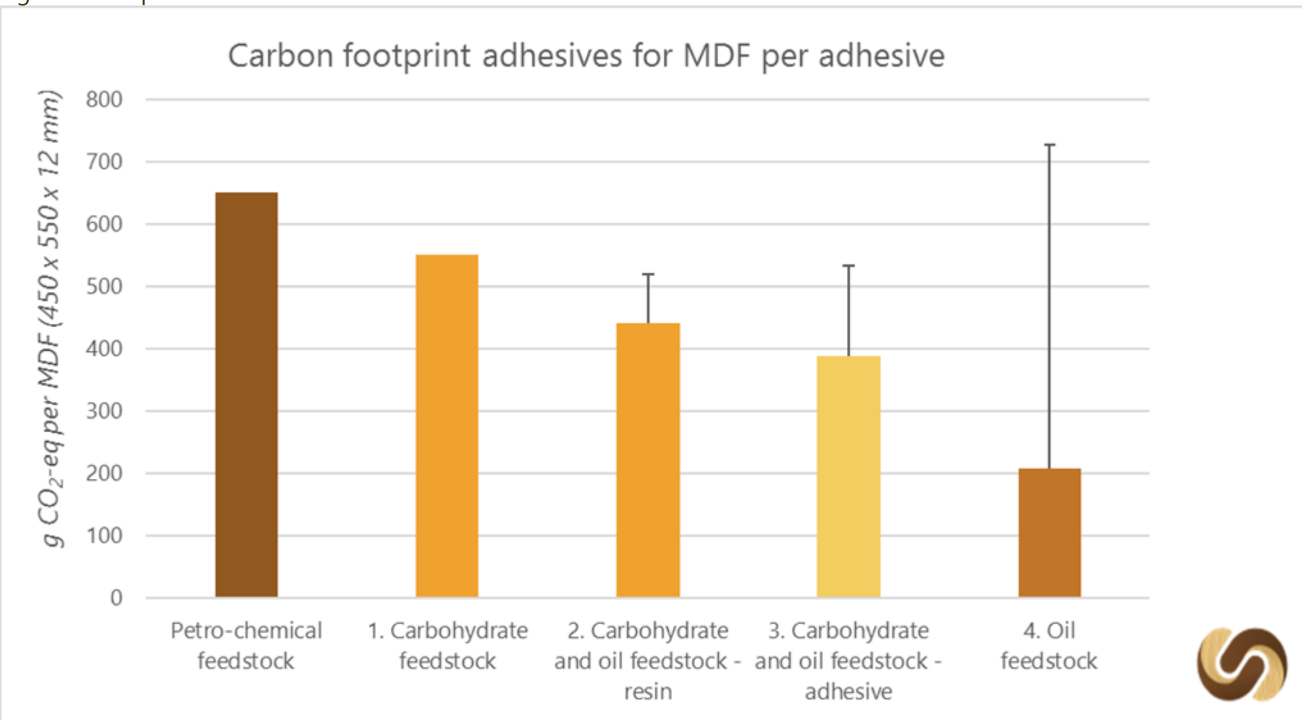
The biggest contributions to the production of the carbohydrate feedstocks are the production of the raw material and the energy used during the production process. For all oil feedstocks, the raw material production, so the cultivation of rapeseed, soybean, sunflower and linseed, has the largest climate change impact.

Figure 1 Comparison of results – P2 PB



Note: Results exclude climate change impact of land use change

Figure 2 Comparison of results – MDF



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Land use change impact results

The analysis of the climate change impacts of potential direct land use change yields the results shown in Table 1. The values in gram CO_2-eq./functional unit (f.u.) should be added to the climate change impact as shown above.

These results highlight that climate change impacts can be substantial and should be taken into account in SUSBIND's decision-making. In addition, it is apparent that certain combinations of crops and adhesive systems cannot achieve SUSBIND's carbon footprint reduction target, since the emissions from land use change far exceed the carbon footprint targets. The safest way to ensure that land use and associated land use change emissions remain as low as possible is to reduce the arable land needed per functional unit (m3 of particleboard or MDF) by using crops that offer the highest yields and feedstocks that use as little raw material as possible.

Table 1 Carbon footprint of direct land use change per type of adhesive

Adhesive system	**Quantity for MDF** 450 by 550 by 12 mm		**Quantity for P2 PB** 450 by 550 by 14 mm	
	Gram CO_2-eq per f.u.	% of carbon footprint without land use change	Gram CO_2-eq per f.u.	% of carbon footprint without land use change
1	57 - 147	11% - 28%	38 - 98	10% - 27%
2	151 - 528	29% - 261%	100 - 351	40% - 174%
3	163 - 679	31% - 176%	48 - 149	14% - 45%
4	376 – 1,885	52% - 907%	250 – 1,253	49% - 740%

Note: Ranges in carbon footprint are due to use of different (combinations of) raw materials

Recommendations

Based on the analyses conducted in this report, the following general recommendations are derived:

- **Types of adhesives**: We recommend exploring adhesive 1 and 2 further. It seems likely that these adhesives can achieve a carbon footprint reduction in comparison to the current petrochemical adhesives. We recommend to only explore adhesive 3 further if an epoxidised oil proves to be a very effective hydrophobic agent. We recommend not to explore development of adhesive 4 further. The risk of land use change, and associated climate change impact due to increased production of oil feedstock is too high.
- **Carbohydrate feedstock selection**: From a carbon footprint perspective it does not matter which type of feedstock is selected (glucose solution, fructose solution or maltodextrin solution). There is, however, a difference in carbon footprint of the two raw materials under consideration (maize and wheat grain), but we recommend to include both in the further development. It is important though to source raw material from the most efficient production locations or to move towards crops grown on marginal lands.
- **Oil feedstock selection**: We recommend not to include linseed oil and soybean oil as possible feedstock in the further development due to the high risk of land use change associated with these types of feedstock. We recommend to include both rapeseed oil and sunflower oil as potential types of feedstock for the use in adhesive 2 or adhesive 3. The use of oil feedstock should however be minimized as much as possible.

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