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

Deliverable 5.4

LCA of adhesive systems

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Publishable summary

Background

The SUSBIND consortium aims to develop a bio-based adhesive system for P2 particleboard (PB) and medium-density fibreboard (MDF) that achieves two main environmental goals: 1) a 5% lower carbon footprint (TRL 5 for bio-based compared to TRL 9 for the fossil benchmark) and 2) lower human health impacts compared to the benchmark.

In the other SUSBIND work packages, the consortium partners have developed a novel partly bio-based and formaldehyde-free resin. This new resin has shown promising technical performance in lab-scale testing and in a prototype IKEA product. The 'SUSBIND resin' is based on fructose derived from wheat/maize, hydroxymethylfurfural (HMF) made from fructose and fossil bis(hexamethylene)triamine (BHT).

In this analysis we compare the environmental performance of the SUSBIND adhesive system to a state-of-the-art UF adhesive system in wood-based boards (P2 PB and MDF). We focus on the carbon footprint (cradle-to-grave) of the boards. In addition, we analyse the first board emission test (emissions during use of the product) results to give a first indication of the human health performance during the use phase of wood-based boards.

Method: life cycle assessment

A life cycle assessment (LCA) is conducted to compare the carbon footprint of the new SUSBIND resin and conventional UF resin when used in P2 PB and MDF. The analysis follows the ISO 14040/14044 standards for LCA (ISO, 2006a) (ISO, 2006b). The functional unit is defined as an adhesive system for 1 m^3 of board, meeting the performance requirements.

'Adhesive system' is defined in this assessment as all non-wood components in the board, i.e. the resin and any additives which contribute to meeting the technical requirements of final board products. In addition, any expected changes in the amount of wood chips or energy needed when switching from one adhesive system to the other are included. This functional unit is chosen because all properties of a board can change when using a different resin, including the amount of wood chips, the type and amount of additives, and the energy use for board pressing.

The LCA uses a cradle-to-grave scope and focuses on current production in Europe. For end-of-life, incineration without energy recovery is assumed.

Primary process data was provided by the industrial SUSBIND project partners. This includes the preparation of UF and SUSBIND resins and the production of PB and MDF boards (i.e. wood chips, resin amounts, additives, energy). This data is supplemented with background data from literature and LCA databases.

In the analysis, different resin contents for the SUSBIND resin are studied, i.e. 12% and 10% resin content for P2 PB, and 12%, 10% and 8% for MDF. Because the required resin contents are not exactly known (further optimisations may be possible), it is relevant to show the effect of resin content reductions. Another resin, pMDI (polymeric methylene diphenyl diisocyanate), was added as a secondary fossil reference for PB, as it is a relevant existing alternative to formaldehyde-based resins for wood-based boards.

Carbon footprint results

The carbon footprint results are shown in **Fout! Verwijzingsbron niet gevonden.** below. In this figure, the red dots show the total (cradle-to-gate) carbon footprint of the adhesive systems. This is based on the default background data. The uncertainty bars (i.e. the black line covering the red dot) show how the results

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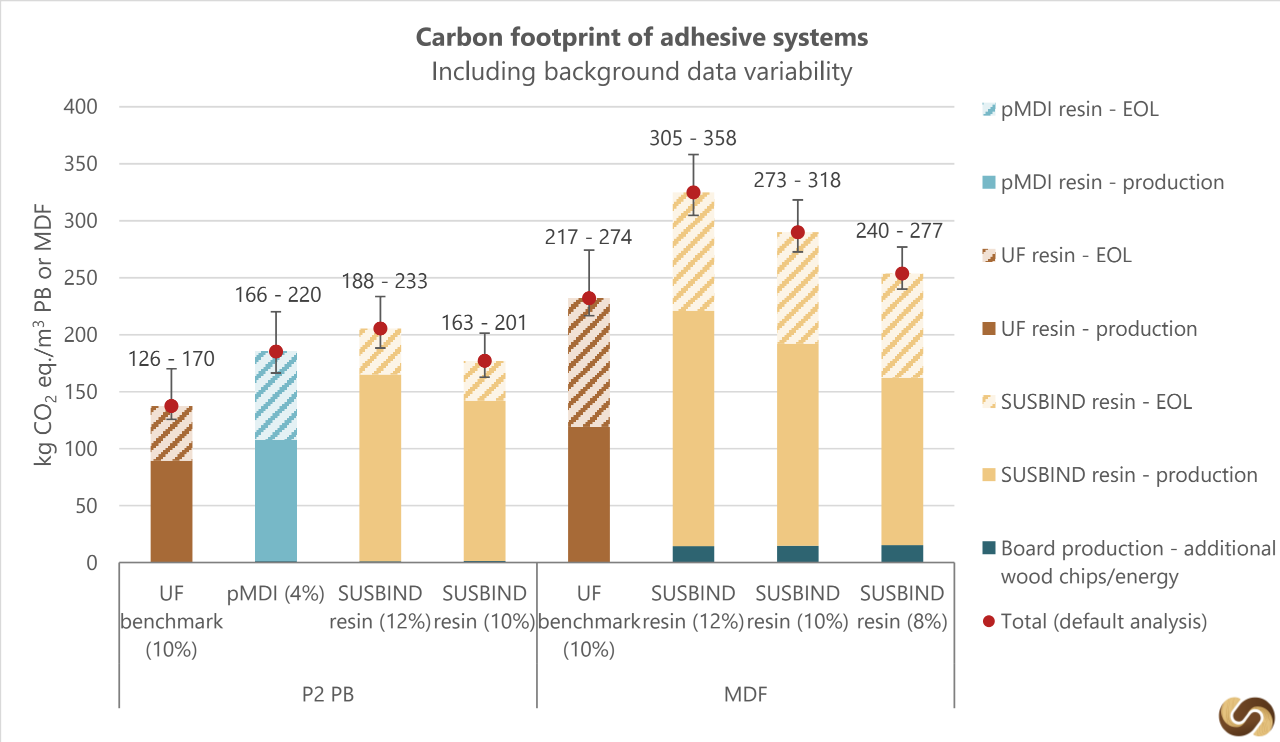
change if different background carbon footprint background data for the carbon footprints of materials are used (e.g. a value for methanol production in Germany instead of a European average for methanol production). The low value of these bars indicate how the carbon footprint would change if all the lowest carbon footprint values are used (lower value) or vice versa for the highest values.

Figure 1 Carbon footprint of all studied adhesive systems in PB and MDF, with uncertainty range for background dataset variability



Compared to the UF benchmark for PB, the SUSBIND adhesive systems (as well as pMDI) are estimated to have a higher carbon footprint. The carbon footprint of pMDI is estimated to be 35% higher, while that of the SUSBIND resin is about 30 to 50% higher, depending on the share of resin content (10% of 12%). However, when compared to the pMDI reference, the SUSBIND adhesive system has about a 5% lower carbon footprint if a resin content of 10% can be used.

For MDF, the carbon footprint of the SUSBIND adhesive system is between 9% and 40% higher, depending on the resin content. Note that all these percentages would be smaller if the entire wood-based board, not just the adhesive system, would be considered.

The largest contributor to the carbon footprint of the SUSBIND adhesive systems is the production of the fossil crosslinker BHT. BHT production accounts for 32% to 50% of the total carbon footprints of the adhesive systems for MDF and P2 PB, respectively. During EOL, BHT is also a large contributor, since it contains fossil carbon. Its EOL contributes between 11% and 17% of the total carbon footprint.

If we consider the variability in the background data (indicated by the uncertainty bars in **Fout! Verwijzingsbron niet gevonden.**), the analysis shows that all carbon footprint values could be 3-7% lower or 5-10% higher. This shows that the carbon footprint of adhesive systems based on SUSBIND resin can be comparable to the fossil benchmarks in specific instances. For example, the uncertainty range for the 10% SUSBIND resin case in PB partly overlaps with the uncertainty range for the 10% UF benchmark. The same applies for MDF in the case of 10% and 8% SUSBIND resin.

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Discussion and conclusions

The analysis contains some limitations that should be kept in mind when interpreting the results:

- The amount of SUSBIND resin required to produce boards with equivalent properties as UF-based boards can likely be optimised further.
- No carbon footprint is available for BHT in LCA databases. The carbon footprint of BHT is therefore determined by using hexamethylenediamine as a proxy, i.e. we are assuming that BHT production has the same carbon footprint as HMD production. Because BHT is a minor co-product created in the HMD production chain, HMD is considered a representative proxy.
- The SUSBIND boards have so far been produced at lab scale, which means that some of the values/assumptions used in this analysis may not fully translate to industrial scale production. We are for instance assuming that additive mixes will be similar and that board pressing energy is identical (P2 PB) or slightly higher in proportion to increased press times (MDF) when making SUSBIND boards compared to UF boards.
- The energy use of SUSBIND resin production is based on an estimate by CE Delft on expected production at TRL5.
- The assessment is limited to the carbon footprint (cradle-to-grave) and human health (use phase only) performance. Other environmental effects have not been studied.

The present analysis leads to the following conclusions regarding SUSBIND's two environmental goals:

- The carbon footprint of the adhesive systems based on the SUSBIND resin is currently estimated at about 180 to 205 kg CO_2 eq./m^3 for P2 PB (between 12% and 10% SUSBIND resin), and 255 to 325 kg CO_2 eq./m^3 for MDF (between 12% and 8% SUSBIND resin).
    - Based on these results, the SUSBIND adhesive systems are estimated to have a higher carbon footprint than the benchmark state-of-the-art UF adhesive systems. The benchmark carbon footprint values are 137 kg CO_2 eq./m^3 for P2 PB and 232 kg CO_2 eq./m^3 for MDF.
    - When compared to using pMDI in PB (185 kg CO_2 eq./m^3), the SUSBIND resin has a lower carbon footprint if the resin content is 10% (or lower).
    - The carbon footprint of the SUSBIND adhesive systems is strongly determined by the use of fossil-based BHT, which has a high carbon footprint (during production and end-of-life).
    - If variability in the available background datasets is considered, the SUSBIND adhesive system can come close to or beat the fossil benchmarks in specific instances.

- A first, indicative analysis of potential human health impacts during the board use phase (Chapter **Fout! Verwijzingsbron niet gevonden.**) shows that SUSBIND boards can emit different substances compared to MUF/UF reference boards, such as much higher acetic acid emissions. While the emissions are different and in some cases higher, the overall human health impact of SUSBIND boards is expected to be lower based on the ReCiPe 2016 human health indicator.
    - The main contributor to the human health indicator are formaldehyde emissions. These are already very low in the MUF/UF reference boards (well below the E1 emission standard and thus considered safe). For the SUSBIND boards, the formaldehyde emissions are even lower.
    - The emissions which were higher in the case of SUSBIND boards (e.g. acetic acid, furfural, butyric acid) have a much lower human health impact compared to formaldehyde according to the ReCiPe 2016 method.

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