Certified Biobased Adhesives for Timber Construction

– The Transition to a Circular Economy with Renewable Carbon

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1. Abstract

The construction industry is undergoing a transformation towards sustainability, specifically with the use of mass timber products as a promising avenue towards not only a circular economy, but also the defossilization of building materials, and the reduction of CO_2 emissions. Central to this transformation is the role of load-bearing adhesives, which enable the construction industry to use modern mass timber products and shift away from concrete and steel.

By enabling timber construction, load-bearing adhesives already contribute significantly to sustainability. Nonetheless, the adhesives industry is constantly looking for ways to improve its products' footprint further to support the transition to renewable materials. This can be done by making mass timber production more efficient, or by enabling a wider use of timber construction; or by increasing the use of renewable carbon in the adhesives themselves.

This paper discusses the integration of renewable carbon resources[1] in load-bearing adhesives as a strategy towards a more circular economy for a reduction in the carbon footprint while advancing defossilization. By showcasing two adhesive products from our portfolio, we demonstrate how incorporating renewable carbon can substantially enhance sustainability in timber construction. The paper also explains the concept of mass balance as a key approach to facilitate the transition to a more sustainable and environmentally responsible future.

2. Introduction

The construction industry is shifting towards environmentally responsible practices, with mass timber construction gaining popularity due to its ecological and economic advantages[2]. Certified load-bearing adhesives have enabled modern timber construction and are thus an important lever to accelerate sustainable construction. However, the adhesives industry also has to constantly address its carbon footprint. The need to reduce carbon emissions and promote circularity and defossilization are critical goals in this context.

This points to a general challenge that adhesives share with most chemical products. By far the largest contribution to the overall carbon footprint of any chemical in a cradle-to-gate view can be traced to the raw materials used[3]. The remainder of the footprint stems from the energy used in production and along the supply chain.

We first draw a parallel to the energy industry. In order to significantly reduce the carbon impact of primary energy use, the industry needs to transition away from the use of fossil fuels to renewable energy. The energy industry has taken first steps by growing the share of renewable energy generation over time. According to the IEA[4] the total generation of electricity from renewable resources increased from 23% to 28% between 2015 and 2021.

[1] vom Berg, C. and Carus, M. et al.
2023: Renewable Carbon as a Guiding Principle for Sustainable Carbon
Cycles. Editor: Renewable Carbon Initiative (ed.), Hürth 2023
[2] UNEP Building Materials and the Climate, 2023
[3] Tamoor, M., Samak, N. A., Yang, M., & Xing, J. (2022). The Cradle-to-Cradle Life Cycle Assessment of Polyethylene terephthalate: Environmental Perspective. Molecules (Basel, Switzerland), 27(5), 1599.
[4] IEA Renewable Energy, 2022

In the same way, the chemical industry needs to transition away from fossil resources to renewable ones. Decarbonization as in the energy industry is not an option since carbon is the essential building block in most chemical products. The task is thus to replace existing products that are made with fossil carbon with those made with renewable carbon sources.

There is a number of pathways to create a circular value chain based on renewable carbon in chemicals.[5] Raw materials can come from biomaterials, recycled materials, or from capturing CO_2 from the atmosphere and converting it to hydrocarbons.[6]

In adhesives, the current focus in the transition from fossil to renewable resources is on biomaterials. Biobased raw materials can come through two different approaches. Firstly, direct biobased molecules can be used to offer a new chemistry, as an alternative to what is used today, for example, lignin and betulin.

Secondly, renewable carbon can enter the existing chemical production as feedstock at the very beginning of the value chain. This usually starts with bionaphtha. Bionaphtha is one of the products derived from the processing and refining of a number of starting materials, such as recycled vegetable oil, bio-waste, or animal fat.[7]

In this second approach a renewable resource (bionaphtha) replaces fossil-based naphtha while yielding the exact same chemical molecules throughout the full chemical value chain.

We argue that both approaches to biobased materials described above are necessary to transition to a sustainable future. Taking the example of two products from Henkel's adhesive portfolio for the timber construction industry, we will show how a transition to a circular economy and a renewable carbon chain can be achieved while reducing the carbon footprint.

3. Transitioning to renewable carbon and sustainable adhesives

The paper presents two examples of sustainable adhesives, a one-component polyurethane adhesive, and a two-component polyurethane adhesive, highlighting the substantial reduction in carbon emissions and increased use of renewable materials. In both cases, around two thirds of the organic material can be based on renewable materials, which similarly reduces emissions by about two thirds.

The adhesives make use of two different pathways, specifically the use of direct biobased molecules and the use of renewable carbon from a biobased feedstock like bionaphtha using the mass balance method. These two pathways are explained in more detail below. We also highlight how the usage of biobased raw materials can be proved and audited along the value chain.

3.1. Direct use of biobased materials

The direct use of biobased materials is to be distinguished from mass-balanced renewable materials (see 3.2). Direct biobased materials utilize chemical molecules derived from renewable resources, such as plants or algae, and available as such molecules (or their precursors) in the plant. The level of renewable content in the final products can vary, ranging from 100% to partial inclusion.

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[5] Henkel. (2022, May 6). A circular economy for carbon – the key to a sustainable chemical industry. https://www.henkel.com/spotlight/2022-05-06-a-circular-economy-for-carbon-the-key-to-a-sustainable-chemical-industry-1657414

[6] Kaiser, Simon & Gold, Stefan & Bringezu, Stefan. (2022). Environmental and economic assessment of CO_2-based value chains for a circular carbon use in consumer products. Resources Conservation and Recycling. 184. 106422. 10.1016/j.resconrec.2022.106422.

[7] Rob Roe. (2022, May 9). Bionaphtha: The Renewable Alternative to Fossil-Based Naphtha. *Omni Tech*. https://www.henkel.com/spotlight/2022-05-06-a-circular-economy-for-carbon-the-key-to-a-sustainable-chemical-industry-1657414#item2

Direct utilization of biobased raw materials offers some advantages. It is a very intuitive approach, and origins are easy to track. Many direct biomaterials offer unique properties. However, the challenge of varying availability and consistency of feedstocks must be considered. Additionally, some direct biobased materials show low thermal resistance, vulnerability to degradation, and low processability[8]. Often there is a need for novel technologies, additional research, and in particular significant investment in new production assets.

To prove the content of direct biobased materials, the final products are regularly analyzed by carbon-14 radiocarbon analysis.

Carbon-14 (C-14) is a radioactive isotope of carbon and occurs in small amounts in the Earth's atmosphere. C-14 is present in molecules of atmospheric carbon dioxide. It is absorbed from the air by green plants via photosynthesis and then passed on to animals through the food chain.

C-14 radiocarbon analysis is like a special clock that helps scientists determine the age of organic substances. When organisms are alive, they keep taking up C-14 from the atmosphere. Once the organisms are dead, they then stop taking it up, so that the amount of the C-14 steadily decreases.[9] By measuring how much C-14 is left in a material, we can estimate how long ago the organism was alive. This functionality makes C-14 radiocarbon analysis a valuable tool for identifying bio-based carbon sources.

By analyzing the C-14 content in a material, researchers can distinguish between carbon that originated from recent biobased sources and carbon that comes from fossil-based sources.

One of our products, the two-component polyurethane adhesive, is partially based on direct biobased materials.

3.2. Mass-Balance Approach

Defossilization, or the shift from fossil-based carbon resources to renewable and circular carbon sources, is a critical process for the reduction of CO_2 equivalent emissions. However, complete defossilization remains a complex and ongoing process, requiring collaboration between governments, industries, and consumers. In order to offer a pathway to a fossil-free future in the chemical industry, it is important to offer a gradual conversion similar to the approach that proved successful in renewable energy.
The mass-balance approach allows companies to gradually integrate renewable and circular carbon resources into their existing infrastructure without requiring immediate and complete restructuring. At the same time, mass balance makes it possible to ensure the correct tracking and allocation of renewable feedstock (the total input and the total output are balanced).

To illustrate the principle of mass balance, we take the electricity grid as an example. The electricity grid is fed by a heterogeneous array of electricity sources, such as nuclear, coal, and solar energy. Consumers have the option to procure either environmentally-friendly energy from renewable sources, or a standard mix, including electricity derived from gas- or coal-fired power plants. Nevertheless, in reality, all electricity generation is combined and conveyed through the identical grid infrastructure to all end users. It is critical that an audit proof system is in place to guarantee that the amount of renewable energy sold matches the amount generated.

Analogously, in the chemical industry, the whole production process can start with renewable carbon resources or fossil-based resources. Consumers may elect either those products produced utilizing renewable and circular carbon resources, or products from fossil-derived materials. In practicality, all raw materials are combined and processed within the same production pipeline, employing a mass-balance methodology.

[8] Abe MM*, et. al*. (2021). Advantages and Disadvantages of Bioplastics Production from Starch and Lignocellulosic Components. Polymers.13(15):2484.
[9] Kutschera, W. (2019). The Half-Life of 14C—Why Is It So Long? Radiocarbon, 61(5), 1135-1142.

This mass-balance approach accelerates the transition by allowing us to use existing assets and prevent unnecessary separation of supply chains. It allows easy use of drop-in renewable-carbon materials in already existing products, processes, and infrastructure. On top of this, and most importantly for timber construction, no additional certification is needed as the product's molecular composition and performance is identical to a fully fossil-based product. The proportion of renewable carbon that can be achieved in the final product depends on real physical pathways through the chemical production chain. Mass balancing does not allow for a CO_2 accounting system in which credits can be bought for claiming 100% biobased in cases where no physical production pathway exists.

To achieve highest transparency and credibility for mass balancing, external certification regimes are essential to prove claims about mass-balanced content. Today, three certification schemes, ISCC[10], REDCert[11], and RSB[12], are generally used for both bio-based and recycled content.

Henkel's two products, both containing mass-balance materials, are certified by ISCC PLUS, a global sustainability certification system. This system emphasizes traceability in supply chains, ensuring compliance with sustainability criteria and credible claims.

4. Biobased formaldehyde-free adhesives for timber construction

Henkel offers a large number of adhesives with varying degrees of biobased materials for a large variety of industries. For applications in timber construction, two products are commercially available that show a significant reduction in the use of fossil raw materials and thus a significant reduction in their carbon footprint.

4.1. LOCTITE CR 821 ECO

LOCTITE CR 821 ECO is a next generation two-component formaldehyde-free polyurethane adhesive that enables sustainable invisible connections of wooden construction elements, combining strength and aesthetics. Robustness and easy handling compared to conventional technologies are additional benefits of LOCTITE CR 821 ECO. It is certified in Europe for glued-in rods and wood connections using steel plates.

LOCTITE CR 821 ECO consists of a polyol part and an isocyanate part, with a volume ratio of 2 to 1, respectively. The polyol part is produced with direct biobased content derived from renewable raw materials, such as soybean oil, rapeseed oil, sunflower oil, and their derivatives. The isocyanate part is linked to 60 weight percent ISCC PLUS certified material via the mass balance approach using bio-circular feedstock. Overall, 71% of the organic mass of the cured adhesive is made from biobased materials.[13]

Looking at the carbon alone, around 75% of the carbon atoms come from renewable sources. We have successfully made a big step in the transition from fossil-based carbon to renewable carbon, which leads to a lower climate impact. LOCTITE CR 821 ECO achieves 62% reduction in the CO_2 equivalent emissions compared to a fossil-based version as confirmed by an inhouse cradle-to-gate life cycle assessment.[14]

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[10] ISCC. (n.d.). *Certification- ISCC System.* Retrieved October 9, 2023, from https://www.iscc-system.org/certification/
[11] REDcert. (n.d.). *REDcert² – for the use for material purposes.* Retrieved October 9, 2023, from https://www.redcert.org/
[12] RSB. (n.d.). RSB is a collaborative network of global organisations advancing the transition to a bio-based and circular economy.. Retrieved October 9, 2023, from https://rsb.org/
[13] Based on LCA information received from the suppliers of the relevant raw materials; figures are subject to changed if suppliers amend or change their raw material LCAs.
[14] European Platform on LCA. (n.d.). *Life Cycle Assessment (LCA).* Retrieved October 9, 2023, from https://eplca.jrc.ec.europa.eu/lifecycleassessment.html

4.2. LOCTITE HB S ECO

LOCTITE HB S ECO products are an extension of the LOCTITE HB S line of one-component formaldehyde free polyurethane adhesive. LOCTITE HB S has been used in the mass timber industry for over a decade, with wide-spread application for the manufacturing of cross laminated timber (CLT), glulam beams, and finger-jointed timber. In the biobased version, 63% of the organic mass of LOCTITE HB S ECO adhesive is linked to ISCC PLUS certified materials via mass balance approach using bio-circular feedstock.[13] These new products achieve a reduction of 66% CO_2 equivalent emissions compared to the fossil-based version as confirmed by an inhouse cradle-to-gate life cycle assessment.[14]

5. Conclusion

The imperative shift from fossil-based to renewable carbon sources stands as a central endeavor across various industries in the forthcoming years. This paper places a distinct emphasis on the significance of this transition and elucidates its practical application in the context of load-bearing timber adhesives, thus contributing to the broader discourse on sustainability.

The transition is highlighted by two adhesive products presented in the paper. Both of the products contain a significant amount of biobased content, exceeding half of their organic mass component, achieving an appreciable reduction in the cradle-to-gate carbon footprint. This substantial reduction, achieved by the utilization of biobased resources, illustrates the potential for sustainable adhesives to advance environmental responsibility.

Sustainable adhesives play a big role for the reduction of carbon footprints in mass-timber products. By directly tapping into biobased resources and leveraging a mass balance approach, these adhesives hold the potential to significantly curtail their environmental impact, thereby contributing to the overarching goal of enhancing sustainability within the building construction sector.