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## Partnership and transparency along the supply chain

# Together towards climate neutrality

## Introduction

The development of sustainable products has experienced some slow progress in the past, as it was mostly based on voluntary commitment. However, more recently the topic has gained strong momentum in the adhesive industry, since the European Commission announced the “European Green Deal” in 2019. This strategic, ambitious package of measures is designed to tackle environment-related challenges, reduce greenhouse gas (GHG) emissions, and enable European citizens and businesses to benefit from the digital and sustainable transition. The goal is to decrease 55% of $CO_2$ emissions in Europe by 2030, make Europe climate neutral by 2050, and, with this, the first climate neutral continent. In 2020 and 2021, China and United States set comparable goals for their nations. Consequently, this topic has now spread widely across our business ecosystem, including customers, raw material manufacturers, suppliers, standardization and certification entities and non-profit associations.

How much we reduce our carbon footprint has become the metric by which all human activities are measured. $CO_2$ is present in the atmosphere naturally and is not harmful per se, as long as it can be recycled within the metabolism of living plants and micro-organisms. Climate damage and its contribution to global warming can, therefore, be quantified by tracing back the amount of $CO_2$ generated by the processing or consumption of fossil-fuel-based raw materials. Read below some measures that can help mitigate that trend.

## 1. Renewable and recycled raw materials

To drive down $CO_2$ emissions of its products, adhesives and sealants manufacturers must first assess its environmental impact by measuring the GHG of direct combustion (scope 1), bought energy usage in its manufacturing processes (scope 2), as well as downstream processes, including transportation, packaging and waste recycling and disposal (scope 3) [Ref. 1]. The ultimate tool for this measurement is a life cycle assessment (LCA). The LCA´s done at H.B. Fuller so far showed us that, and depending on the technology, up to 85% of the product related $CO_2$ emissions are determined by the raw materials used. Therefore, a strong focus is being put on raw materials made of alternative feedstocks to drive the carbon footprint down.

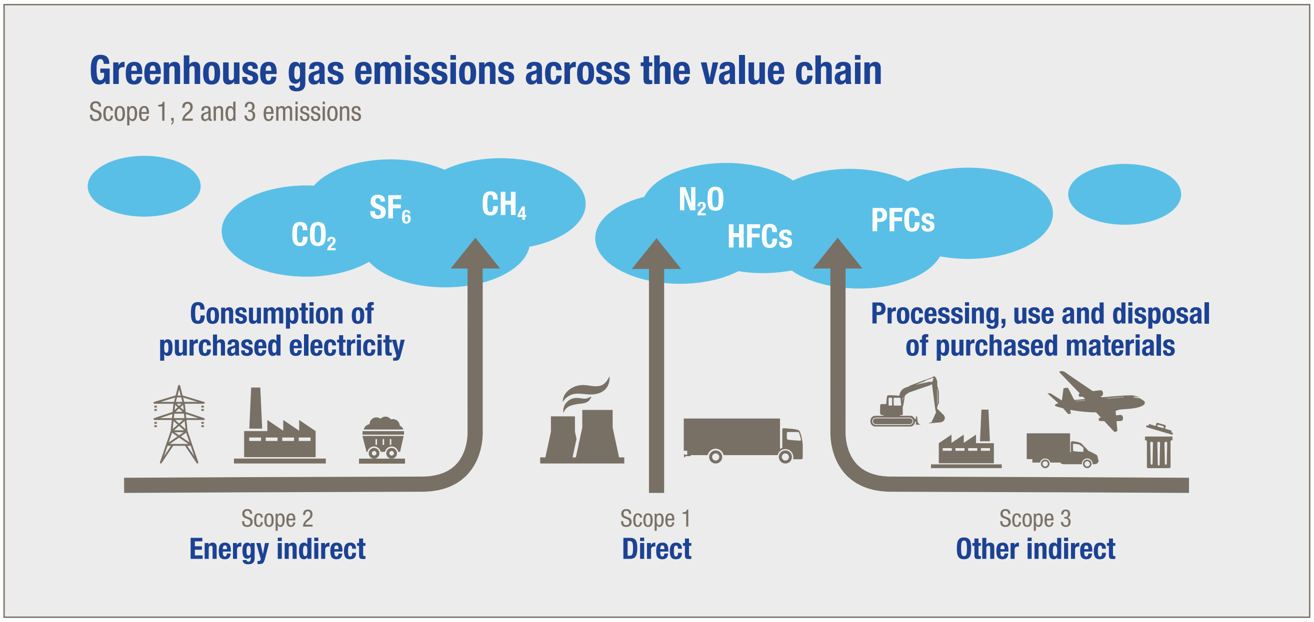


Fig. 1 - Greenhouse gas emissions across the value chain. Source GHG Protocol

### a. Life cycle analysis

Life cycle assessments analyze a product's inputs and outputs to determine its potential contribution to global warming, including GHG emissions and other effects, like water scarcity. Most companies focus on the evaluation of $CO_2$ emissions as a starting point. These types of product-related analyses are usually requested as "cradle-to-gate" (from creation to factory production) and are offered by various service providers in accordance with DIN ISO 14040 and ISO 14044.

The individual elements that compose a product can be measured separately, which is useful when determining the $CO_2$ footprint of a finished adhesive product, particularly when a formulation combines segregated and mass balanced raw materials. By convention, renewable (e.g., biomass) and $CO_2$-based feedstocks are generally assigned a negative PCF (Product Carbon Footprint) value, because they have captured a specific proportion of carbon dioxide from the atmosphere. Conversely, fossil-based raw materials are assigned a positive PCF value. For recycled materials, the $CO_2$ footprint must be determined accordingly, but it is usually well below that of fossil-based raw materials. Using LCA methodology to measure the impact of a formulated adhesive means the sum of the total of all "outputs" (product, by-products, and waste) and the total of all "inputs" (raw materials, auxiliary materials, energy requirements, packaging, and transport).

In addition to the LCA, a "cradle to gate" analysis requires suppliers to provide the $CO_2$ footprints of not just raw materials used, but also the packaging and any other materials. And this is where collaboration and transparency along the supply chain becomes crucial. The transfer points at the factory gate must be clearly defined so that the sum of all "gate-to-gate" elements ultimately provides an overall picture of the product's impact from production to the end of its useful life.

The steps of use, recycling and disposal also must be evaluated, as well as further stages for reprocessing, if these are considered necessary to close the loop. If a product life cycle ends with disposal in the form of landfilling waste or thermal treatment through waste incineration, the life cycle is called, "cradle-to-grave." The carbon quantities generated in this way have a significant impact on a product-specific $CO_2$ balance.

## b. Importance of Certification

There are many certification models available for the purpose of traceability and transparency, like the ISCC PLUS standard or the REDcert2 standard. Whereas ISCC (International Sustainability & Carbon Certification) is a global association that aims to provide a recognized certification system for sustainability and greenhouse gas savings and that initially was created for agricultural activities, the REDcert standard has its roots in the provision of biofuels and goes back to the Renewable Energy Directive (RED) of the European Commission. Both have recently been extended to the requirements of the circular economy, including the supply chains of the chemical industry. All types of biomass and their derivatives can be certified that way, and it has been expanded to recycled materials, which may be the more scalable option for manufacturers aiming to reduce their $CO_2$ emissions.

These certifications also establish rules according to the different chain of custody models (ISO 22095).

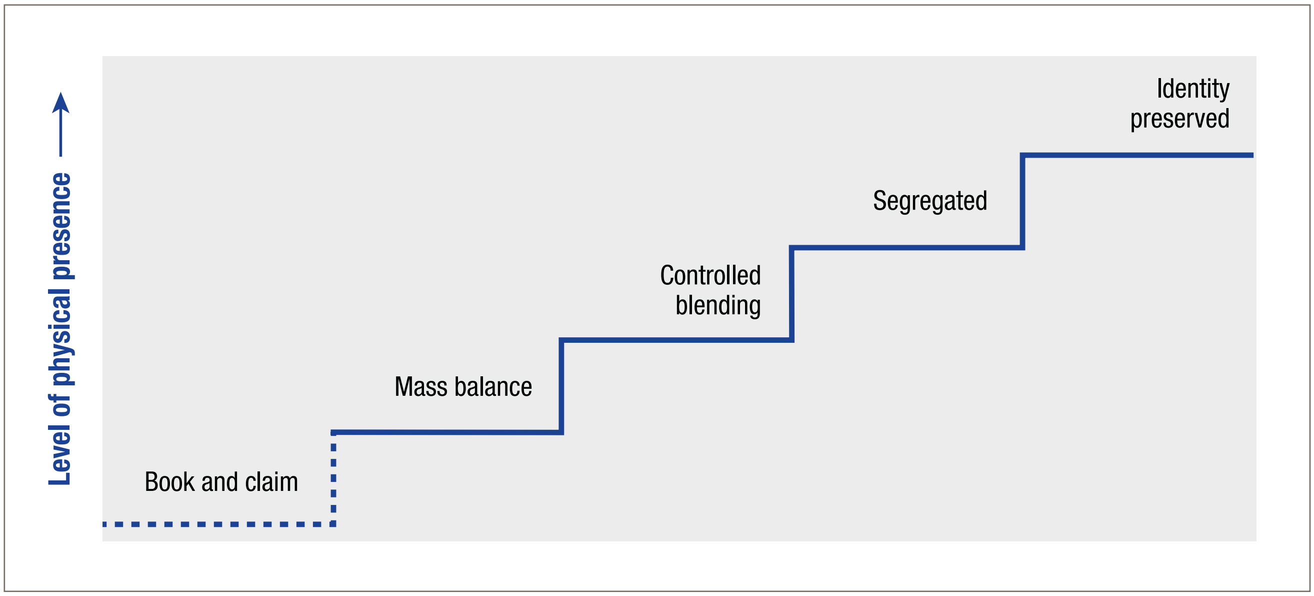


Fig. 2 - Illustrative example of chain of custody models

ISCC PLUS and REDcert2 are globally recognized standards, and they are closely linked to the United Nations Sustainable Development Goals, like:

1. Protection of biodiversity
2. Compliance with sustainable agricultural standards
3. Occupational safety
4. Protection of human, labor, and land ownership rights
5. Compliance with international laws and agreements
6. Quality assurance standards (good management practice and continuous improvement)

The compliance with the global standards is monitored by external auditors.

### c. Segregated materials

One way of reducing the $CO_2$ footprint of a product is to replace formulation components in whole or in part with renewable raw materials, also known as bio-based raw materials. Raw materials that are chemically derived from modern biological sources (not fossil-based), essentially come down to five different substance classes:

- Oils and fats (i.e., rapeseed, oil, palm oil, linseed, etc.)
- Polysaccharides and derivatives (i.e., starch, sugar, cellulose, lignocellulose from forest waste, corn, cane sugar, sugar beets, straw and cotton)
- Proteins (i.e., rapeseeds, dairy products)
- Complex bio-molecules (i.e., natural rubber, silk, yeast and mushrooms)
- Biomass (i.e., mixtures of substances from biological waste) [Ref. 2]

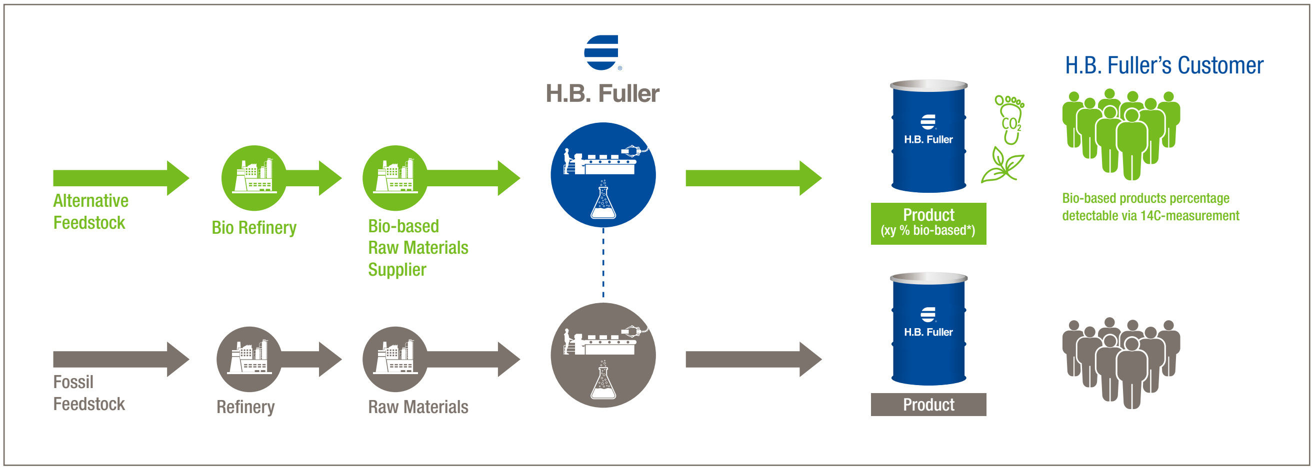


Fig. 3 - Segregated processing of alternative feedstock

However, there are two main issues with these sources because they are limited; first in chemical diversity, e.g., there are few aromatic building blocks, and second in volume. In 2019, biopolymers only made up 8% of total global polymer demand, including over 80% of already known and widely used materials, such as natural rubber, cellulose, and natural fibers. Therefore, the chemical intermediates that are important for adhesive formulators, only amount to roughly 3 million tons worldwide (as of 2019), of which only around 3% ultimately benefit the adhesives industry [Ref. 3]. Nevertheless, many of our customers currently want the use of bio-based raw materials, as their renewable carbon content can be clearly determined using the radiocarbon method (ASTM 6866:20).

Biological raw materials are complex. They almost never occur in nature in their pure form, but rather bring with them by-products from which they need to be separated. In some cases, this is not possible physically, so chemical digestion processes and derivatizations must take place in order to produce the desired starting material at the required purity. Biological raw materials can, therefore, only be used in exceptional cases as a one-to-one exchange in formulations.

Additionally, and to achieve the same mechanical properties, the adhesives often require reformulation. It also is possible that synthetic routes that have so far hardly been used, lead to new substances that require REACH certification, which can involve high administrative and financial hurdles. Another obstacle is the inadequate infrastructure for industrial up-scaling of these biomaterials, if produced in a segregated way. Even if the decisions to scale up were made quickly, a new plant is not built and ready for operations overnight.

A particularly illuminating method of reducing $CO_2$ emissions is to create new materials from the carbon dioxide in the atmosphere or from industrial exhaust gases in which the carbon dioxide is particularly enriched. This is possible today using special catalysts, e.g., the production of polycarbonate diols, which can already contain up to 50% $CO_2$. Current research projects deal with artificial photosynthesis, which is a pioneering achievement regarding an energy turnaround, with the aim of producing specialty chemicals and a green hydrogen economy. Most of those products, however, are still under development and not yet available.

### d. Mass balanced materials

Mass balancing of alternative feedstocks, being of biomass or recycled origin, can represent an interesting alternative to segregated raw materials. All in all, it can help to bridge the gap until the demand either makes an investment in new assets economically sensible, or when those assets being used today for various sources can be completely filled with alternative raw materials in the future [Ref. 4].
Thus, the mass balance approach is used when chemicals and intermediate products are manufactured on the same facilities as conventional products, but the raw materials can already be partially replaced by renewable raw materials.

To document and prove the associated reduction in the $CO_2$ footprint, the concept of mass balancing allows for the attribution of specific characteristics of biological or recycled feedstocks to the final product [Ref. 5]. In those instances, the manufacturers declare a certain share of their production to be attributed from renewable resources, in proportion to the share of the feedstocks. The allocation must be verifiable, based on accurate bookkeeping, and audited and certified by third parties for full transparency.

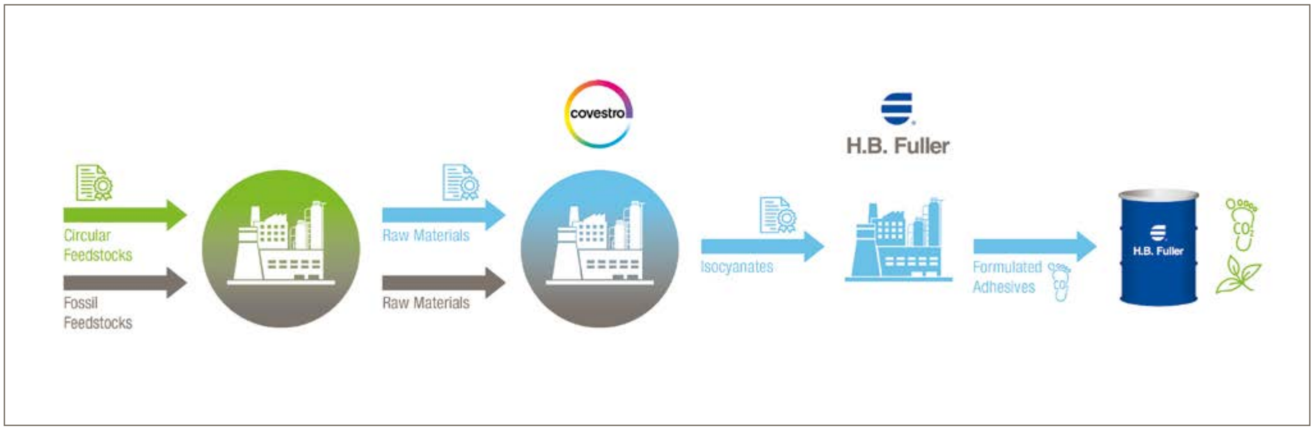


Fig. 4 - Explaining the Mass Balance Approach. The new ingredient in our adhesive is a bio-attributed raw material created via a mass balance approach

Due to its comprehensive and transparent multi-stakeholder approach, the ISCC PLUS standard is becoming widely recognized, as it only declares that portion of a product as being bio-attributed, which is physically or chemically linked. This can be identifiable through clearly defined process steps at a production site. In that case, the attribute of i.e., biological origin is determined by the portion of the product that comes from the recipe, the stoichiometry, or the yield of the reaction.

This interpretation of those mass balanced products is closer to a “controlled blending” type of chain of custody model, whereas other approaches like i.e., RED Cert 2 follow the chain of custody model of “mass balance” more conceptually and, therefore, go up to 100% of bio-attributed content of a product. This view might be somewhat challenging in the sense of understanding but provides a less complex approach for recycled materials use when it becomes more circular and repetitive in the future.

Recently, H.B. Fuller has announced a partnership with Covestro, one of the world's largest polymer suppliers, to deliver an ISCC PLUS certified Isocyanate used as an ingredient for the formulation of a reactive hotmelt adhesive. Besides the certification, Covestro provides the LCA data of their products, bio-attributed via the mass balance approach, to ensure a "gate-to-gate" transition. The formulated adhesive demonstrates identical product quality and properties and has no effect on our customers' manufacturing procedures. The new, renewable-attributed adhesive product can be treated and processed in the same way as the product it replaces.

With this approach, we can contribute to the circularity of the industries, offer more sustainable products, enable companies to reduce their own emissions, and replace finite fossil resources with renewable raw materials in their own products.

## 2. Promoting the development of sustainable products at H. B. Fuller

- Seeking new ways to lessen environmental impact
- Partnering along the supply chain to contribute to the company sustainable goals
- Combining all available renewable raw materials to help reduce $CO_2$ footprint without compromising performance

We are committed to developing the appropriate technical competencies to drive sustainable product development across our three global business units (GBUs) – Engineering Adhesives, Construction Adhesives, and Hygiene, Health and Consumables Adhesives.

Bonding disparate substrates, such as plastics, metals, mineral materials, glass, wood, and fiber composites could require high energy usage. The use of technical adhesives is indispensable to conserve resources, both in the manufacture of components made up of a wide variety of materials and in the selection of the joining technology. These types of solutions serve a large set of functions in the manufacture of vehicles, electrical and electronic devices and "white goods", to name a few. In addition to the actual load transfer, they also contribute, for example, to lightweight construction, which, as in the case of fiber composite materials, is only possible through adhesives. The longevity of such bonds has been a contributing lever in terms of energy and material efficiency to help combat climate change.

We believe that, by being involved in the conception and design of the products at an early stage, we can partner with our customers to ensure final product cycles are already carefully thought of and included in the design. This is the right way to achieve meaningful recycling and prevent down-cycling, which in turn also helps our customers meet their own sustainability goals and consequently contribute to the overall climate action.

## 3. Summary

We are assisting at a strong political and social awareness that is demanding concrete actions and legislations to limit climate change. Industries around the world are being impacted and need to continue developing the most efficient means of reducing the greenhouse gas. This is an essential task that presents unique challenges, but also opens the way for innovation and differentiation, and thus creating added value for customers.

Due to its versatility and flexibility of working with various segments, technologies and raw materials, the adhesives industry has many options available to help lead the journey. And we can already see different approaches arising in the various areas of application. Sustainable transformation is not a standalone challenge of single players but requires the commitment of the whole ecosystem. We joined forces to bring trust into new approaches to create more sustainable adhesives and to accelerate the increased utilization of more sustainable feedstocks and, in turn, reduce the dependency from fossil sources.

By joining this effort, adhesive manufacturers as well as brand owners, are enabled to promote products with $CO_2$ footprint reduction backed with a collaborative LCA calculation along the value chain.

The “cradle-to-gate” LCA, with focus on product-specific footprint, is currently the most practical way for adhesive producers to balance their efforts in combining the various raw materials in one formulation and in supporting “cradle-to-grave” or even “cradle-to-cradle” analysis. By doing this in conjunction with customers, we will be better at determining and redesigning a possible reduction of the PCF at the end of the product life.

We trust that through stronger standardization and constant improvement of data quality, operations, and recycling processes, along with independent recognized certifications, a clearer picture will emerge, on where adhesive technology further showcase their greater potential towards sustainability.

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