**VCI Position**

The use of renewable raw materials in the chemical industry, applying mass balance approaches

**Renewable raw materials in the chemical industry**

Renewable raw materials – like vegetable oils, animal fats, starch, sugar or cellulose – have been established for a long time in the chemical industry. They have manifold fields of use, ranging from the production of surfactants for detergents, fibres, lubricants, hydraulic oils, paints and coatings, plastics, cosmetic agents, adhesives or building products to medicines. In total, the chemical industry in Germany used 2.7 million tonnes of renewables in the year 2013.

**Bio-based products**

When renewable raw materials are processed separately from fossil raw materials (in so-called dedicated facilities), then the products physically contain the renewable carbon from the renewable raw materials and are called “bio-based”\(^1\). In practice, bio-based products often consist of so-called blends, i.e. mixtures of both renewable and fossil raw materials. Here, various production methods are used for various product applications.

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1 For precise definition see CEN/TC 411, cp. Annex: answer 4, page 9
Complex production systems

The case in fig. 1 shows a highly simplified, ideal case. While renewables are mostly used in special applications, the production processes are usually not separated.

In principle, multi-stage and multiple branched value chains are characteristic of the chemical industry’s production structure. Chemical products are produced in complex processes and – in view of technical and economical availability of means of production (raw materials, production plants and know-how) – quite often at separate sites and in different regions globally, and by different suppliers and service providers in the value chains. Therefore, separating bio-based and fossil material flows is not possible or hardly efficient due to the described complexity of both the processes and the supply chains.

Another characteristic feature of the chemical industry’s production structure is its high resource efficiency, which, among other things, is a result of many years of optimisation and integration. Many thousands of products for the chemical industry’s customers are based on a small number of fossil resources (e.g. naphtha, natural gas). These are usually different from many bio-based raw materials, so that they cannot always be fully substituted – and issues like process adaptation, comparability and value of the raw materials need to be carefully considered.

To increase the use of renewables in chemical production – beyond existing applications – two strategies could be considered:

1. Building new value chains based on renewable resources

Separate production plants allow the production of bio-based products as shown in fig. 1, which can meet the relevant customer requirements. Usually the property “bio-based” is also the prerequisite for being able to pass on higher costs for renewables and new production methods and plants to the customers – through higher sales prices. But the past has shown that building new dedicated value chains in interplay with various actors is a huge challenge. It was possible in recent years to produce a small number of molecules with entirely new properties from bio-based raw materials, but these still have a very low share in total production. And it will take time until the share in total production of molecules from bio-based raw materials will be high enough to make it economically viable to invest billions in dedicated production facilities. Moreover, in most cases bio-based products are not the final products. Therefore, the production of a “bio-based final product” with a distinct bio-based carbon content per CEN TC 411 would necessitate a strict separation of bio-based and fossil material flows in the entire value chain. In most cases, this is neither possible nor efficient.

2. Integration in complex production systems and supply chains

Where, on the other hand, renewables are integrated in existing production and supply chains, efficient and flexible processing is fostered. The high yields and economies of scale of established and optimised plants can be utilised also for
the initially small volumes of renewables (= high efficiency), and no new production plants need to be built along the entire value chain. In this way, it is possible to use renewables for a multitude of mass products and thus to contribute to a bio-economy and to climate protection. From a technical point of view, this is perfectly possible if the renewables have the properties required for their processing. In economic terms, this is feasible only if the renewables can compete in respect of costs or if a demand from customers can be met with them. However, using renewables in complex production systems and supply chains does not result in (purely) bio-based products which physically contain the renewable carbon from the renewables and can be marketed as such. Here, mass balancing offers a solution. It enables attributing (allocating) the used renewable raw materials to products: through accounting.

The mass balance method

In the mass balance method, the volume of renewables is attributed (allocated) to selected products, according to their individual formulation – i.e. taking into account all yields and losses. For this purpose, the renewable raw material must be used within one clearly defined system boundary. The fundamental prerequisite is a well-settled input-output balance – i.e. it must be ensured that the volume of raw materials used as input for the balanced products (“output”) is actually used in the system boundary and that the volume of the renewable raw materials used as input is solely and correctly accounted for within the defined system boundary to avoid double counting and ensure additionality. Only raw materials used as feedstock (but not as energy) for the production should be considered for mass balancing.

SYSTEM BOUNDARY

The system boundary is determined by the user of mass balancing. It needs to be clearly defined and include all production facilities that are linked with each other for mass balancing. A system boundary is given where a potential physical substance stream between the renewable raw material (input) and the product (output) is possible – be it within the same company, within a group of companies or in special contractual relations between independent companies of the value chain, while the actual transport of the products is not required.

MASS-BALANCED PRODUCTS

Products are mass-balanced products when bio-based raw materials or intermediates were verifiably used within a defined system boundary. It is possible that biogenic carbon is no longer detectable in the final product, due to timing or dilution effects, or the division of labour along the value chain.

To document the use of renewables as input within the system boundary, a suitable verification and certification system needs to be used.
TRANSFER

Within the system boundary, mass balance is made by a book transfer of the biogenic properties of the bio-based raw materials to the final products in which biogenic carbon is not (or no longer) detectable in sufficient quantities to qualify as “bio-based” per CEN/TC 411. The amount of the transferred biogenic properties needs to be documented along all production steps from the point of entrance of the bio-based feedstock into the system boundary to the last step of producing the final mass-balance product using auditable accounting systems which exclude double counting. The predefined system boundary and the presence of contractual relationships is what distinguishes the transfer of properties within a value chain for the purpose of mass balancing from other book-keeping systems, especially those of the “book and claim” type.

Three application cases can be distinguished

Case 1: Transfer in productions with time fluctuating feed-in

Bio-based raw materials and intermediates are either processed in continuous processes alternating with their fossil counterparts or the feed-in of bio-based and fossil raw materials is not constant over time. This leads to products whose biogenic carbon content either fluctuates over time or where biogenic carbon can be detected in the final product at a certain point in time (time 1) but not at another point in time (time 2). Because the products have no other structural differences, separate processing for technical reasons is not necessary and a separation is not always possible, either. This means, however, that biogenic carbon is not detectable at all times in the final product due to the described transfer, even though it was used in the production chain.
Case 2: Transfer in integrated production (Verbundproduktion)

At many sites, chemical production is characterised by integrated productions (Verbundproduktion) where a small number of fossil-based basic chemicals is converted to a multitude of products. The interlinking of production steps and the internal recycling of substance flows (e.g. for by-products or solvents) can be further characteristics of integrated productions. Depending on the number of process stages within a complex production system, final products of an integrated production – at the beginning of which renewables as well as fossil raw materials were used – contain only a low bio-based share or a bio-based share which is not even measurable. This can be the case where there is a dilution effect below the detection limit.

In integrated production (case 2) it should be additionally ensured for mass balancing that additional amounts of renewable raw materials are actually used. This is relevant if a company already uses renewable raw materials in dedicated facilities elsewhere. Otherwise, these amounts already used for dedicated production could be also be accounted for in mass-balancing, without the company having to use additional renewable raw materials.
Case 3: Multi-site transfer and local balancing in global manufacturing supply chains

Comparable with integrated production at one site, it is also quite usual in the chemical industry to carry out individual process steps at different sites and to finally manufacture the final product at even other locations close to the end customer. For example, in region 1 intermediate A for product X is available from a renewable raw material, while in region 2 the same intermediate A to produce the same product X is made from a fossil raw material. To avoid the transport of intermediates or products across regions, the documented use of the biogenic raw material is credited to the product obtained from the fossil intermediate and, at a later stage, to the final product.

In this case, mass balancing along the entire value chain must ensure that the product produced from the renewable raw material does no longer claim this property for itself ("chain of custody" approach; avoiding double counting). Like in integrated production (case 2) it must be ensured that additional amounts of renewables substitute fossil raw materials.

**Distinction from bio-based products is necessary**

The definition per CEN/TC 411 requires bio-based products to contain a minimum share of biogenic carbon measurable with the C14 method (reference: standard ASTM D6866). No such bio-based share needs to be physically contained in mass-balanced products. Products to which renewable raw materials were attributed in mass balancing are not bio-based per CEN/TC 411. This distinction needs to be made and clearly communicated towards both B2B customers and final consumers.
THE VCI IS CALLING FOR THE FOLLOWING:

- Renewable raw materials can be used both in dedicated production processes for the manufacture of bio-based products and in the above-described production scenarios: integrated production, fluctuating production processes, complex supply chains. Therefore, new methods like mass balancing approaches, which contribute to sustainability and resource efficiency, should have their place and equal standing in the bio-economy.

- To convey to customers and consumers the difference between bio-based products and products based on mass balance approaches, the VCI supports the development of standards for defining mass balancing and connected transfer approaches for biogenic properties and, beyond that, standards for clear and understandable communication.
Annex: Questions & Answers

1. What are mass-balanced products?
Mass-balanced products are products where bio-based raw materials or intermediates were verifiably used as feedstocks (i.e. not as energy) in the production. The renewable raw materials used are attributed (allocated) to selected products by way of calculation, while the biogenic carbon used in the production process may not be detectable in the final product. The mass-balancing method requires the attribution (allocation) of the quantity of renewables used to certain products according to their individual formulation, i.e. taking into account all yields and losses.

2. Why can biogenic carbon not be reliably detected in the final product if the use of bio-based raw materials and intermediated can be proven?
There can be several reasons:
- For example, the bio-based raw materials and intermediates can be processed in continuous chemical processes alternating with their fossil counterparts. Consequently, biogenic carbon may be detected in some products, but not in others. Other than this, there are no other structural differences between the products, so separate processing for technical reasons is not necessary and may not be feasible, either. Depending on the time samples are taken, it is possible that no biogenic carbon is detectable in the final product.
- As long as the demand for bio-based products is low, renewable raw materials or intermediates can be processed together or combined with their fossil counterparts. In this case, a dilution effect can lead to concentrations below detection limit.
- Depending on the type of raw material or intermediate, incomplete blending or mixing of the feedstocks or intermediates (e.g. in delivery or storage) can be the cause of a lack of detectability of biogenic carbon in the final product.
- No biogenic carbon is physically contained in the product to which the biogenic properties are transferred during a balancing across different geographic production locations or along supply chains.

   The fact that biogenic carbon is physically present in a product does not automatically mean the product is more sustainable than its fossil counterpart.

3. What is the difference between mass-balanced and bio-based products?
According to the definition of CEN/TC411 (see below) a minimum percentage of biogenic carbon must be detectable in bio-based products, measurable with the C14 method (reference: ASTM 6866 standard). No such share needs to be detectable in mass-balanced products.
4. What is the definition of „bio-based“ under CEN/TC 411, and where can it be found?

http://www.cen.eu/work/areas/chemical/biobased/Pages/default.aspx

Internet search of 24 February 2017

The following is a selection of terms and definitions as published in the European Standard EN 16575:2014 ‘Bio-based products – Vocabulary’. If a new version of EN 16575 is published, these terms and definitions might be outdated. Readers are encouraged to check EN 16575 for the full list of terms and definitions.

2.1 Bio-based = derived from biomass

Note 1 to entry: Biomass can have undergone physical, chemical or biological treatment(s).

Note 2 to entry: The correct spelling of "bio-based" is with a hyphen (-). It is however in common usage sometimes spelt without a hyphen.

Note 3 to entry: The methods to determine and communicate "bio-based" as a characteristic are detailed in specific standards of CEN/TC 411.

2.2 Bio-based carbon, biogenic carbon = carbon derived from biomass

Note to entry: Biogenic carbon is defined in ISO/TS 14067:2013, by the same definition.

2.4 Bio-based content = fraction of a product that is derived from biomass

Note 1 to entry: Normally expressed as a percentage of the total mass of the product.

Note 2 to entry: For the methodology to determine the bio-based content, see FprCEN/TR 16721.

2.5 Bio-based product = product wholly or partly derived from biomass

Note 1 to entry: The bio-based product is normally characterised by the bio-based carbon content or the bio-based content. For the determination and declaration of the bio-based content and the biobased carbon content, see the relevant standards of CEN/TC 411.

Note 2 to entry: Product can be an intermediate, material, semifinished or final product.

Note 3 to entry: "bio-based product“ is often used to refer to a product which is partly bio-based. In those cases the claim should be accompanied by a quantification of the bio-based content.

2.7 Biomass = material of biological origin excluding material embedded in geological formations and/or fossilized
EXAMPLES (whole or parts of) plants, trees, algae, marine organisms, micro-organisms, animals, etc.

2.8 Biomass content: see bio-based content

2.14 Product = substance, mixture of substances, material or object resulting from a production process

Note 1 to entry: Product can be an intermediate, material, semifinished or final product.

2.15 Renewable material = material that is composed of biomass and that can be continually replenished (SOURCE: adapted from EN ISO 14021:2001)

5. Why is mass-balancing being performed?

Thanks to the variety, high yields and economies of scale of established and optimised industrial plants, small volumes of renewables can be used to manufacture almost all products (→ high efficiency). Here, mass-balancing helps the chemical industry to use bio-based raw materials and intermediates as feedstocks without constructing new, separate production plants for their processing or without shutting down and then restarting existing plants for each production batch. The customers of the chemical industry do not need to expect any changes in application, either, as mass-balanced products have no structural difference to their fossil-based counterparts. On the condition that mass-balancing is made in a credible manner, it can also benefit the customers of the chemical industry: With technical properties remaining unchanged, a credible sales claim (use of biomass at the beginning of the production chain) is possible. This saves investment costs for the customers of the chemical industry (including for small and medium-sized enterprises/SMEs) and increases efficiency, as large plants can be operated more efficiently than small ones. In addition, resource efficiency increases, as no losses are incurred due to products not meeting specifications during shutdown and restart phases of plants, and as feedstocks and energy are used exclusively for products according to specification.

6. Does mass-balancing stand in the way of innovation?

No, quite the contrary is the case. Innovation takes place e.g. with suppliers of biomass, as the biomass needs to be prepared for use in the chemical industry (e.g. catalysts, biotechnology). Furthermore, the balancing approach is intended for the most efficient use of biomass in the large-scale production of substances/products – it is not meant to replace research into new molecules or the development of more specific solutions. There is also the option of using (bio)waste as feedstocks at the beginning of the value chain and to assign its biogenic properties to selected final products by means of mass balancing.
Intermediates in the chemical industry are substances and products which are obtained by chemical and/or biochemical processes and which can serve as production inputs to produce further products (e.g. surfactants, lubricants, polymers or specialty chemicals). To make novel intermediates from bio-based feedstocks, new technologies (e.g. biotechnology, application of novel catalysts) are necessary. As these bio-based intermediates – as constituents of new chemical products or specialty chemicals – are initially not needed in volumes large enough to necessitate the construction of dedicated production plants, the development and use of the new technologies depend on the acceptance of mass balancing. Only mass balancing enables the cost- and resource-efficient production of products using bio-based feedstocks in existing plants and supply chains without efficiency losses, which could also pay for the development costs of new technologies. This creates an incentive for developing various new technologies to produce bio-based intermediates.

Also, the chemical industry manufactures many specialty products whose formulations are tailored for the respective use requirements. For such products, dedicated production relying on bio-based feedstocks would not make sense from both an ecological and economical point of view. For specialty products, mass-balancing can therefore enable an increased use of bio-based feedstocks.

7. Is a physical connection between the renewable raw material and the product a prerequisite for mass-balancing?

A physical connection between the renewable raw material and the product is not required for mass balancing with transfer, but such connection needs to be possible based on concrete corporate or special contractual relations between actors in the value chain (“chain of custody” approach), whereas mass-balancing without transfer requires a physical connection. If no such connection is either mediated by a physical substance stream or corporate or special contractual relations, the term commonly used is “book & claim”.

8. What is not included in mass-balancing with transfer?

Not included are conventional “book & claim” approaches where the information about the use of biomass as raw material is transferred independent of a potential physical substance stream and/or without corporate or contractual relations.

Is a physical connection needed for mass-balancing with transfer?

Only the possibility of a physical substance stream within corporate or special contractual relations must exist.

For mass-balancing with transfer – do renewables/intermediates need to “flow” physically, or is it sufficient that this possibility exists?

It is sufficient that this possibility exists, mediated through corporate or special contractual relationships.
9. Is it possible to use mass balance products as inputs at a production site?

This is possible.

An example is bio-methane which was fed into and taken from the natural gas grid. Bio-methane itself is a product obtained from biogas according to a mass-balance approach. The C14 content is detectable only temporarily or at certain system boundaries.

10. Does the raw material need to be used as feedstock, or can it also be used for energy?

Mass-balancing shall only be applied to material use. Therefore, only biomass used as feedstock can be credited to a chemical synthesis by way of mass balancing. Concepts for compensating fossil by renewable energy use are currently under discussion.

Take the example of bio-gas: can it also be used as a fuel, or does it have to be used as a material feedstock? In mass-balancing, bio-gas or bio-methane can be credited only if used as material feedstocks (e.g. in ammonia, synthesis gas, hydrogen or downstream products).

11. Does the raw material used as feedstock need to enter the same process chain from which the target product originates?

Some stakeholders demand that the used biomass needs to distribute itself based on the stoichiometric relationship to the so-called C1 and C3 value chains. This demand and the question whether the above should lead to special sales claims is currently still being discussed by various users of mass-balancing methods. For these reasons, the standardisation of mass-balancing approaches should also include the transfer of biogenic properties. This transfer comprises both the attribution of biomass against the chemical flow direction and stoichiometry and the multi-site transfer in global supply chains. From an overarching perspective, it can be noted that every use of biomass in the defined system boundary leads to savings of fossil raw materials and to greenhouse gas reductions – irrespective of the stoichiometric tracking of the C1 and C3 chains.

12. Can the different use application cases 1-3 be combined?

Yes.

13. Are the renewables used as feedstocks certified for their sustainability?

This is up to the individual company. A standard might lay down relevant requirements
14. Can mass-balancing cause misunderstandings and confusion with genuinely bio-based products?
Confusion can occur where it is not clearly communicated that mass balanced products are not bio-based. Therefore, close attention must be paid to the product claim in order to avoid misunderstandings and confusion.
VCI recommends certification and checking.

15. How can double counting be avoided?
Within the system boundary, the biomass used as feedstock and the type of transfer can be tracked precisely. Balancing needs to be done in such a way that the amount of balanced renewable raw materials does not exceed the amount of renewable raw materials used.
Double counting can also be avoided by means of certification.
A “chain of custody” approach avoids double counting.

16. How can the procedural instructions of a mass-balancing exercise be reliably followed and checked?
One way of doing so is using standards and certification. Here some examples:
- For example, TÜV SÜD offers such a certification standard.
- The plastics producing industry is working on the development of an “industry self-declaration”.

17. Do mass-balanced products offer a CO₂ advantage?
Whether or not mass-balanced products offer a CO₂ advantage needs to be demonstrated on a case-by case basis by comparative life cycle assessments (LCA). A standard might stipulate relevant requirements (see answer 16).