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Identical Product Properties – Chemical Products Based on Renewable Resources through Use of the Mass Balance Approach

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BASF has anchored sustainability in the company’s philosophy “We create chemistry for a sustainable future”. Since renewable raw materials can have an impact in this regard, the company further intensified its research and development efforts for products and production processes based on use of renewable feedstocks in 2014. While fossil resources will continue to play an important role in the chemical industry, BASF is addressing the growing customer interest in materials derived from renewable raw materials more actively than in the past. An important component in the concept of resource efficiency is the “Verbund” principle that is employed at six facilities. During integrated production within the BASF “Verbund”, byproducts or waste heat from a plant are used at another location and in this way contribute to efficient utilization of resources.

The new process described in the following, where the “Verbund” principle and the use of renewable raw materials are combined, represents a further step that BASF is taking toward implementation of sustainable development in the chemical industry.

**BASF mass balance approach**

Many BASF customers would like to have products that conserve fossil resources to a greater degree. To address these requests, a concept that was new to the chemical industry, the so-called mass balance approach, was extended further in 2014. Together with TÜV SÜD, the company developed it for flexible use of renewable resources in integrated production.

In the mass balance approach, renewable resources such as bio-naphtha or biogas are used together with fossil resources already in the very first steps of chemical production. The bio-based amount is then allocated mathematically to specific products sold by means of a certified method.

The product sold is certified by TÜV and chemically identical to its conventional, fossil-based counterpart. As a result, there are no quality or property differences. Customers have a solution that can be employed with all existing processes, approvals and certificates i.e. a drop-in solution. Since the existing infrastructures at BASF and customers can be used, i.e. no new equipment or technologies need to be set up, this innovative method can already be applied today and contribute to sustainability.

BASF utilizes only raw materials that, in conformance with the EU definition in the area of biofuels (RED)[1], emit at least 35% less CO₂ during combustion than their fossil counterparts. Thus, products obtained from the mass balance approach can also be credited with making a corresponding reduction in greenhouse gases. The use of renewable raw materials in the course of production based on the mass balance approach contributes not only to conservation of fossil resources, but also to reduction of greenhouse gas emissions.

**Comparable to use of “green” electricity**

The mass balance principle is not a new discovery made by BASF and is already being used for many areas such as bioenergy, by the Forest Stewardship Council (FSC) for wood products or for Fair Trade certified chocolate [2]. A mass balance process is being used, for instance, during feeding “green” electricity into the grid, when two products can no longer be differentiated physically (e.g. production from biomass) but nevertheless specific properties need to be allocated to one product.

With the mass balance approach used by BASF, renewable raw materials are employed together with fossil raw materials simultaneously at the beginning of the production chain (Fig. 1). Sequential use of raw materials would not be practical from an ecological or economical standpoint, since this would involve consumption of raw materials for startup and shutdown procedures without already yielding products, which would be a contrary to sustainable use.

Based on the mass balance approach, the amount of renewable raw materials used can be allocated to specific products in accordance with their individual formulation, i.e. after considering all yields and losses (Fig. 1). The concept thus involves a mass-balanced allocation of the used renewable raw materials for a specific product. Whoever purchases a mass-balanced product can rest assured that BASF has used renewable feedstock to replace the corresponding quantity of fossil raw materials. Depending on the customer’s wishes, between 25 and 100% of the feedstock needed can be replaced with the certified raw material.

![Fig. 1: Principle underlying the mass balance approach.](image-url)
Raw material requirements

BASF sets very high standards for the raw materials used in the mass balance process: They must come from verifiable environmentally sound and socially responsible production and contribute to reduction of greenhouse gases. At present, biogas obtained from agricultural or kitchen waste as well as certified sustainable bio-naphtha are being used. Bio-naphtha is a paraffin hydrocarbon similar to fossil-based light naphtha; it is derived from plant-based oils and organic residues. In compliance with internationally accepted sustainability criteria (e.g. ISCC[3], RSPO[4] or other certification systems recognized by the RED[1]), the raw materials are, together with the suppliers, developed further in terms of sustainability. Besides greenhouse gas reduction, these sustainability criteria include sustainable use of land, protection of the natural environment and social sustainability.

Verification and certification

In parallel with the mass balance approach, BASF also offers its customers products from dedicated processes in which biomass is converted into bio-based products through fermentation or chemical reaction (e.g. BDO, Ultramid Balance). Since these processes are available to only a limited degree on a production scale, mass balance products can supplement these approaches or may even represent the only way to produce a product from biomass.

Dedicated processes permit a qualitative verification of the origin of the carbon contained in the end product as being from biomass (14C radiocarbon method). For products based on the mass balance approach, this is not necessary. There, the emphasis is on the amount of sustainable raw materials used in production and the resultant conservation of fossil resources.

To verify use of sustainably produced bio-based raw materials, a reliable, independent certification system was developed jointly with TÜV SÜD Industrie Service GmbH has many years of experience in the field of energy and sustainability certification.

The certification method for mass balance products includes all steps in the production of a product and a review of the amounts of bio-based raw materials used annually. This means that all substances used, even substances that are not present in the end product (e.g. solvents), are accounted for over the entire production period instead of just through spot checks.

By combining products from the mass balance and dedicated approaches (Fig. 2), customers have the ability to optimize the benefits for their end product in terms of various criteria (e.g. maximum CO₂ savings, conservation of fossil raw materials or the bio-based content of the end product) by choosing from a spectrum of possibilities.

First high-volume use of compounded polyamide

As the first customer for compounded plastics from BASF, Kunststoffwerk AG Buchs, a subsidiary of Wiha Werkzeuge GmbH, has processed and used the engineering plastic Ultramid B3EG6 MB for production of its Longlife brand of meter rules. The polyamide used here is one of the first “mass balance” products from BASF to find use in a volume production application (Fig. 3).

According to the certified balance method, 100% of the fossil raw material needed for production of Ultramid B3EG6 MB are replaced with renewable raw materials already at the beginning of the production process. The abbreviation “MB” designates calculation via the mass balance approach. The certified MB plastic is identical to its fossil-based counterpart in terms of formulation and quality, and is already available in commercial quantities. Kunststoffwerk AG Buchs has also been certified by TÜV SÜD regarding its use of Ultramid B3EG6 MB. This involves an annual review of the entire value chain on the basis of high quality standards all the way to the end product. For suppliers as well as end customers, this assures the source of the raw materials and the sustainability of the concept.

BASF also offers Ultramid (polyamide) based on the mass balance approach for production of flexible packaging film or textile fibers. In the meantime, TÜV SÜD has issued certificates for additional BASF products such as superabsorbers and dispersions and some intermediate products (Fig. 4).

Fig. 2: Mass balance compared to dedicated production

Fig. 3: Meter rule produced by Kunststoffwerk AG Buchs from Ultramid B3EG6 MB

Fig. 4: The formulations on the certificates that TÜV SÜD issues read “Fossil Resources-Conserving Product. x % of the fossil raw materials needed to make this product were replaced with renewable raw materials at the production site”. The additional commitment by BASF itself includes further the reduced greenhouse gas emissions in tons of CO₂ per ton of product resulting from use of sustainable raw materials and replacement of the fossil raw materials for this product. The certificates are collected in a database at TÜV SÜD (http://www.tuev-sued.de/ER-ID)
Mass balance and polyurethanes

Many polyurethane customers of BASF are also asking whether alternative raw materials are available on the basis of renewable raw materials for their products. For thermoplastics such as polyamides (PA), dedicated product grades based on renewable feedstocks derived in part from castor oil are already available today, e.g. Ultramid Balance (PA 6.10). In the past, there were numerous scientific and commercial attempts to produce polyurethanes from renewable raw materials. The attempts on the polyol side were more successful. Here, several commercially available polyols based on oil or sugars have been developed. These include, for instance, the castor oil-based Lupranol Balance from BASF. The isocyanates pose a considerably more difficult challenge. No realistic approach for serving a mass market has yet been found here [5].

For many dedicated products produced from biomass, the chemistry and thus the engineering properties of the resulting polyurethane change when the raw material base changes. These are associated with lengthy and expensive adaptation processes for the user. For high-quality plastics in particular, bio-plastics can be used only with technical compromises. Moreover, it is usually not possible to achieve a content level of 100% renewable raw materials. These cases are niche solutions for the most part.

With the mass balance approach, BASF solves precisely this problem for the PU system and TPU products, and is finding great interest among initial PU customers who value conservation of fossil raw materials and greenhouse gas reduction. For the first time, these customers are able to produce polyurethane products where the polyols and also the isocyanate component are generated from use of biomass. The product properties remain unchanged regardless of whether 25 or 100% of the fossil feedstock is replaced on the basis of mass balance. A further benefit for the customers is that processing in existing machinery does not require conversion.

PU applications that come into consideration here include, for example, refrigerator insulation. About one-third of a refrigerator consists of plastics. If only all of the polyurethane insulation in the refrigerator were produced using the mass balance approach on the basis of biomass, renewable raw materials would already represent 50% of the total plastic content of the refrigerator. By extending the approach to other plastic components such as thermoplastics, the content can be increased to over 90%.

Many refrigerator manufacturers already have defined resource efficiency and CO₂ reductions as corporate goals. Current measures include reduced use of material or energy savings during production or operation of the refrigerator. Use of mass balance products from BASF, in this case the Elastocool PU system, can make a significant contribution to CO₂ reduction and resource conservation.

Furniture manufacturers are also evaluating their products on the basis of sustainability criteria. Some employ EPDs (Environmental Product Declaration), which can indicate very quickly the effects of replacing fossil raw materials with biomass in the value chain and what changes result in terms of greenhouse gas emissions and resource conservation. For an office chair that, besides metal, consists largely of polyamide and polyurethane plastics, 50–60% of the plastics can be provided using the mass balance approach on the basis of renewable materials. Fig. 5 shows an office chair that is still based on fossil polyurethane raw materials.

For upholstered furniture, cushions and mattresses, up to 95% of the fossil-based materials can be replaced with polyurethane components based on the mass balance concept. By using the mass balance approach of BASF, even the PU system or TPU content in a shoe, regardless of whether leisure, safety or sports shoe, sandal or boot, could contribute to reducing the amount of greenhouse gases associated with production of this shoe. Depending on the Elastopan (PU system) or Elastollan (TPU) grade used, and whether an outer and/or inner sole is involved, more than 70% of the fossil raw materials in the entire shoe sole could be replaced by using the mass balance approach of BASF.

Outlook

With the mass balance approach, BASF offers a solution for customers who want products based on renewable raw materials that have the same product and quality properties as their fossil-based product counterparts. In this way, BASF is expanding its range of products and giving customers the ability to replace up to 100% of the fossil raw materials with renewable raw materials. The innovative mass balance approach gives the polyurethane customers of BASF the ability not only to differentiate themselves in the market, but also to contribute to conservation of fossil resources and greenhouse gas reduction. They thus contribute to sustainable development. The technical implementation at BASF has been completed and initial products are available in almost all sectors. Now the market must determine how quickly and to what degree this innovative approach for using renewable raw materials will spread in polyurethane production as well as in the entire chemical industry.

4) RSPO: Round table on sustainable palm oil, http://www.rspo.org/
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