An Eco-Efficiency Evaluation. Use of renewable resources is currently being actively researched. Before they can be used, the environmental compatibility, economic aspects and social impact over the entire life cycle, including production and disposal, must be investigated. If the results are not positive, there are alternatives that do not rely on biomass, since innovative petrochemical plastic products are saving enormous amounts of energy and thus lowering CO_2 emissions already today – and the potential is not yet exhausted.

According to estimates, the amount of corn needed for bioplastics – in the form of starch and PLA (polylactic acid) – is less than 0.1 % of the corn grown worldwide

Bio – Sense or Nonsense

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Over the long term, renewable energy sources and biomass can replace and complement the limited amount of fossil fuels and raw materials to some degree. Against this backdrop, renewable resources will become increasingly important in the future. Per se, however, they are not necessarily good as a material to be used, just as petroleum is not necessarily bad as a material to use. The amount of oil, gas and coal on the Earth is limited, but renewable resources are not present in limitless amounts either. On the one hand, they must grow again and on the other hand they have a number of competitors: wheat, corn (Title photo) sugar cane and rice are first and foremost foodstuffs. However, they are also used to generate electricity and heat. They are used to produce biofuels and serve as raw materials for the chemical industry. BASF has used bio raw material for a long time, e.g. to manufacture paints and coatings from natural resins and oils, vitamin B2 from vegetable oils, amines and acrylates from molasses and cane sugar. Use of renewable resources is actively being researched. However, the company uses these materials in larger amount only where it makes sense ecologically and economically. The amount of renewable resources currently purchased by BASF accounts for less than 5 % of the total purchasing volume.

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It's Also Possible without Bio-based Resources

When it comes to the various possibilities for using renewable resources, the same criteria must be employed as have been to date in terms of life cycle assessments (LCAs), i.e. the environmental compatibility, economic aspects and social impact over the entire life cycle of products, including the associated manufacturing processes and disposal methods, must be investigated. Time and again it is found that a product based on biomass in not per se ecologically more efficient than a petrochemical-based product. Each case must be evaluated individually: if renewable resources are readily accessible, i.e. short transportation distances, do not require excess amounts of water or fertilizers, then use of biomass as a source for material is ecologically beneficial. If, however, large amounts of forest must be cleared or processes that consume large amounts of energy are needed to refine the biomass, the ecological benefit can easily be reversed.

For a correct assessment, aspects such as energy and water consumption, generation of greenhouse gases and discharges into water, e.g. as the result of overfertilization, must be taken into consideration, along with the amount of land required ▶

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for cultivation. On the economic side, the costs for growing and refining the biomass must be compared with the price of oil. Experts in the plastics industry know that there are ways to reduce fossil fuel consumption and CO_2 emissions without resorting to biomass. Use of innovative petrochemical-based plastic products is already saving enormous amounts of energy through efficient insulation of buildings, lightweight construction of automobiles and in the packing of transported goods and holds even greater potential (Fig. 1). A study conducted by the Association for Comprehensive Analyses (Gesellschaft für Umfassende Analysen; GUA) has reached the conclusion [1] that completely eliminating the use of plastics in Western Europe alone would result in a 26 % increase in energy consumption and 56 % higher greenhouse gas emissions. Thus, in the opinion of many participants, setting quotas for biomaterials in this complex field is more likely to be counterproductive.

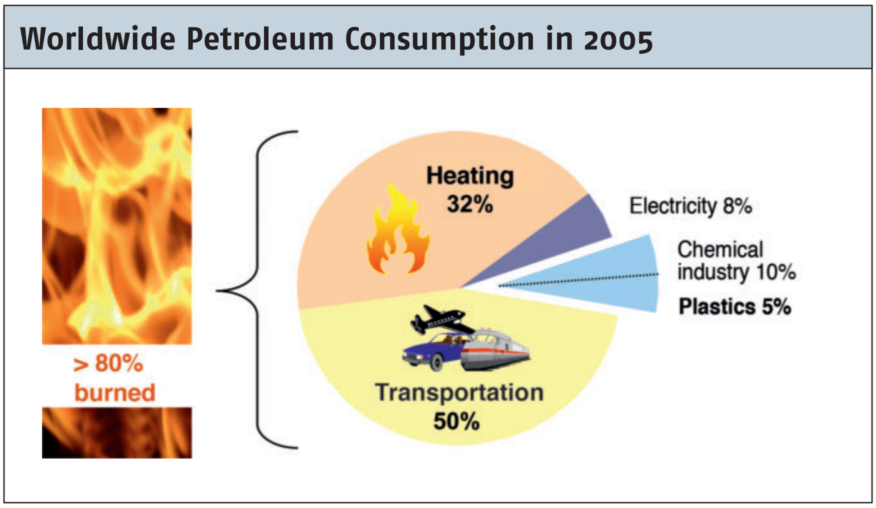

Fig. 1. More than 80% of the petroleum consumed worldwide is "burned" for heating and driving; only a small percentage of the fossil resource oil is used for production of plastics (source: ExxonMobil, Wintershall)

Bioplastics versus Feeding the World

Viewed globally, significantly more land would need to be cultivated than is currently available to meet the demand for fuel in Germany or the EU on the basis of biomass. The much lower amount of biomass needed for the anticipated amount of bioplastics, on the other hand, can be provided without difficulty. This also means that bioplastics would not compete with food production: according to BASF's estimates, the current consumption of bioplastics worldwide is max. 80,000 t. Other estimates come up with a figure of 200,000 t. Even with this higher figure for consumption, the amount of corn needed – in the form of starch and PLA (polylactic acid) – for bioplastics amounts to less than 0.1 % of the amount of corn grown worldwide – which is about 700 million t.

Biodegradable versus Bio-based

As a result of the growing interest in renewable resources and the omnipresent term "bio", a misunderstanding has arisen that often leads to mix-ups. However, it should be made clear that the properties "biodegradable" and "bio-based" do not necessarily have anything to do with one another (Fig. 2). "Bio-based" indicates the origin of the material, whether from renewable or fossil resources. In contrast, "biodegradability" addresses where the material ends up at the end of its life. And since the origin and destination need not necessarily be coupled, it is possible that a bio-based plastic part is disposed of in a waste incinerator or a blast furnace, while a biodegradable bag (as defined in DIN EN 13432) derived from a classical petrochemical source ends up in a composting plant.

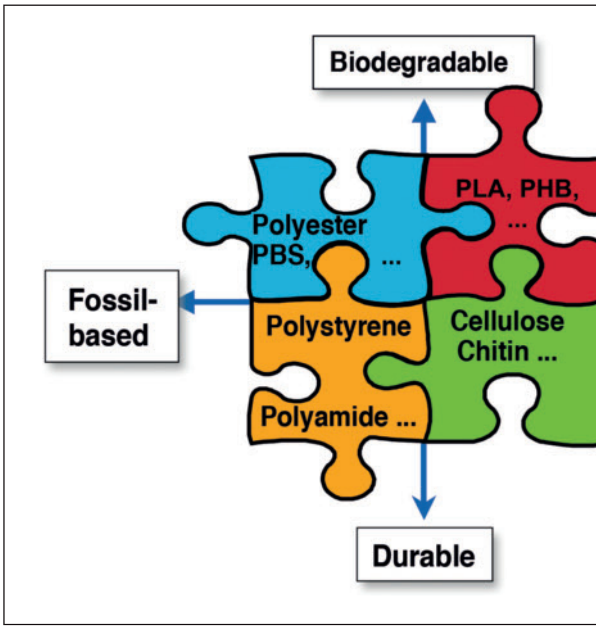

Fig. 2. The plastics family: bioplastics as defined here include biodegradable and bio-based plastics

Doubly Bio-based

Production of plastics from bio-based polymers is a new field and still requires intense research and development. The common bio-based polymers today are PLA and PHB (polyhydroxy butyrates). PLA is produced from lactic acid via polycondensation; the lactic acid, in turn, is obtained from the fermentation of starch. PHBs are polyesters that are obtained from sugar through the action of microorganisms. Compared to conventional plastics, the properties and performance capabilities of both polymers are limited. A different approach is involved when not the polymer itself is obtained from nature, but rather its chemical constituents, which otherwise have their origin in petrochemistry. Plastics produced in this way offer the same capabilities as the fossil-based analogs. Polyethylene (PE) is a representative of this group in which exactly the same material is obtained from bio-based components: the resource (ethanol) can be obtained from sugar cane, so that the resultant product can be called bio-based PE.

The BASF products Ultramid Balance, a PA 6 10 based on sebacinic acid that is obtained from castor oil, and Lupranol Balance, a polyol used for production of polyurethane and also based on castor oil, are members of this group. In the case of such special products, the use of components from renewable resources can make sense, and not primarily because they originate in nature, but because they permit production of a product with special properties. With regard to PA 6 10 in comparison to PA 6, this means considerably less water uptake: this predestines this product for new applications. According to BASF, use of renewable resources must lead to a combination of eco-efficiency and improved performance of polymeric materials. To distinguish excellent from inappropriate applications of bio-based/biodegradable plastics, eco-efficiency analysis, a kind of LCA that was co-developed by BASF, is the means of choice. With the aid of such an analysis, various product and process alternatives can be compared on the basis of the entire life cycle – including aspects such as energy effects, environmental and social impact associated with production, transportation, use and disposal. Such an analysis must be conducted for each individual application and cannot be transferred from one application to another – from a plastic bag to agricultural film or a hamburger container – without an exact calculation.

Focus on Biodegradability

About ten years ago, BASF was one of the first companies to introduce a plastic that, like other conventional plastics, was based on fossil raw materials, but was completely biodegradable. Biodegradable means that the material can be metabolized by living microorganisms. Under composting conditions, ideally in an industrial composting facility with optimized conditions – a high temperature, high humidity, defined oxygen level (DIN EN 13432) – the material is converted completely to water and CO_2 by fungi or bacteria (Figs. 3 and 4). For this plastic, with the trade name Ecoflex and a property profile very similar to that of classic polyethylene, there is, in contrast to PE or PP (polypropylene), a unique method for disposal after use: composting. This is a major difference in comparison to the packaging materials mentioned, but not the only one: as a high-grade material, Ecoflex also offers special barrier properties, e.g. its high water vapor permeability, which predestines it for fruit and vegetable packaging, where it helps to prevent growth of mold. Accordingly, its barrier properties and, above all, its compostability (and fermentability) must be taken into consideration when assessing optimal use: in what applications is it beneficial to have a compostable plastic that is tear-resistant, waterproof, puncture-resistant, printable and water vapor-permeable? It is beneficial in carrier bags that – ideally after being used several times – serve as garbage bags for organic waste, in agricultural film (where it can be plowed under) and in food packaging that can be placed in the container for organic waste ▶

Fig. 3. Fossil-based biodegradable plastic Ecoflex satisfies the stringent requirements of the most important international standards for biodegradability and compostability: the figure shows, from left to right, decomposition of an Ecoflex film within four weeks in compost at a temperature of 55 °C

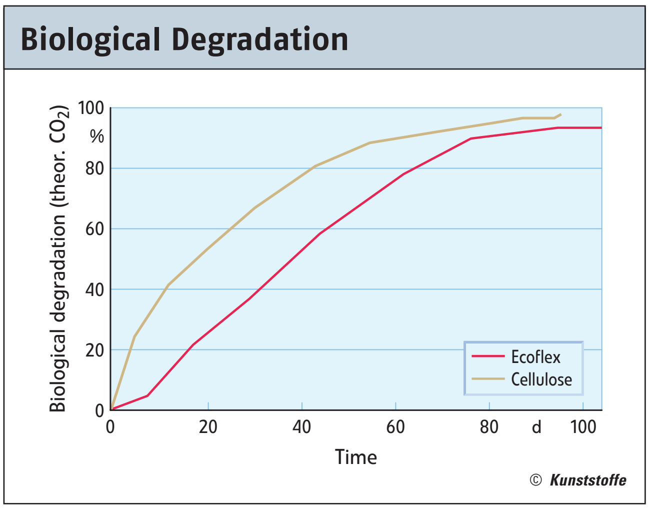

Fig. 4. The degradation curve shows that Ecoflex is more than 90% decomposed after 80 days and thus biodegrades completely much faster than required by the Standard EN13432-Part 2

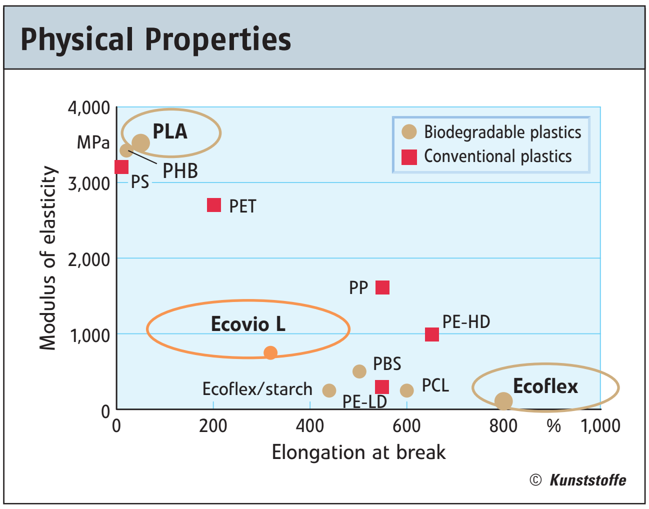

Fig. 5. Ecoflex and Ecovio (= Ecoflex/PLA blends) offer a wide range of material properties: depending on the proportion of Ecoflex or PLA, the plastic becomes stiffer (modulus of elasticity) or flexible (elongation at break)

along with food remains. These are – rapidly growing – niche markets, and a plastic that can occupy such niches offers additional benefits over PE and PP.

Biodegradable and Bio-based

The growing use of renewable resources to manufacture products has opened up an additional field of application for Ecoflex. Since the plastic exhibits good compatibility with starch, cellulose, lignin, PLA and PHB, it is possible to create various blends that, on the one hand, are completely biodegradable, and, on the other, contain a high proportion of renewable resources. For this reason, BASF calls Ecoflex an "enabling polymer" or "enabler", which means that the material makes it possible to use renewable resources. Most renewable raw materials such as corn starch do not have good physical properties and are often neither waterproof nor puncture-resistant. PLA, which is produced from corn starch, is brittle in its pure state and thus more difficult to process than conventional plastics.

To process biomaterials on high-performance machines efficiently, and convert them into high-grade end products that are still biodegradable, an effective blend component is required. As Fig. 5 shows, various stiffness/flexibility profiles can be achieved by mixing starch or PLA with Ecoflex, so that stiff shells as well as flexible pouches and film are feasible (Fig. 6).

Fig. 6. Film made of Ecovio becomes waterproof and tear-resistant by its share of Ecoflex

Fig. 7. A biodegradable carrier bag (left) can be used after shopping as a garbage bag to collect organic waste

Why Composting?

Use of biodegradable plastics is of interest especially if the products can provide economical and/or ecological benefits beyond simply "disappearing from view" by being buried in the soil or incorporated into the organic waste stream.

If conventional plastic garbage bags for organic waste are not to be separated from their contents in a time-consuming process, then incineration remains the only possibility for disposing of the filled bags. This makes no sense from the energy standpoint, since organic waste is about two-thirds water. If, however, a biodegradable garbage bag is used, separation is not necessary – the organic waste together with the bag undergoes organic disposal. There are various possibilities for this approach: first of all, composting; secondly, anaerobic fermentation during which the biomass is converted into biogas (methane), providing a source of energy.

Composting is important especially in some southern European countries where soil erosion poses a serious problem. Biodegradable plastics assist in this regard by providing a clean sorting mechanism for organic waste for production of high-grade compost as a soil improvement. In this way, biodegradable plastics represent not only a cost-effective disposal solution, but can also make an important contribution to efficient management of organic waste. Biodegradable carrier bags can make a similar contribution: after shopping, they can be used for collection and disposal of organic waste; the bag sees double use – as a shopping bag and as a garbage bag (Fig. 7).

Conclusions

Experts as well as the interested public and even politicians, who can send the right or wrong signals through subsidies and quotas, must remember one thing when it comes to the complex topic of renewable raw materials in general and so-called bioplastics in particular: only consideration on a case by case basis provides information on efficient use of resources. A polyethylene shopping bag is not bad per se nor is vegetable packaging made of starch necessarily good. ■

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