WHITEPAPER

GREEN MATERIALS:
BIOBASED PLASTICS

LAPP

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CONTENT

1. STRUCTURE OF A CABLE

LAPP cables can perform a wide range of different tasks and are suitable for thousands of applications. A cable is an electrical conductor sheathed with insulating materials. The history of LAPP begins in 1957 with the invention of the first cable with different colour-coded cores.

Figure 1 shows the basic structure of a cable in a simplified way. The copper conductors themselves are sheathed with an insulating material, such as Polyvinyl chloride (PVC) or Polyethylene (PE). This is primarily used to insulate the individual conductors from one another. Depending on the application, an inner sheath or shielding made of copper braiding or foil may be necessary. The outer sheath, for which different plastics such as PVC, Thermoplastic polyurethane (TPU) oder Thermoplastic vulcanizate (TPV) can be used, protects the cable against mechanical loads, mixed chemical substances and temperature influences. Each of these layers therefore fulfils a very specific purpose and is made of a very specific plastic that can perform this function.

Figure 1: Simplified construction of a cable[1]

2. CAN PLASTICS BE SUSTAINABLE?

Not only in the cable industry, plastics are one of the most important materials for modern society as a whole: Whether as sterile products in medical technology, as insulation materials for energy-efficient buildings or as protection for perishable foodstuffs, plastics fulfil a wide range of functions without which our modern standard of living would not be possible. The global consumption of plastics is correspondingly high. In 2021, more than 390 million tonnes of plastics were produced (see **Figure 2**). Due to the low density of plastic, a unique selling point of plastic compared to many other materials[2], this mass corresponds to a much larger volume than would be the case for metal, for example.

1 Cables and wires | LAPP Online Shop
2 BONTEN, Christian. Plastics Technology: Introduction and Fundamentals. Carl Hanser Verlag, 2019.

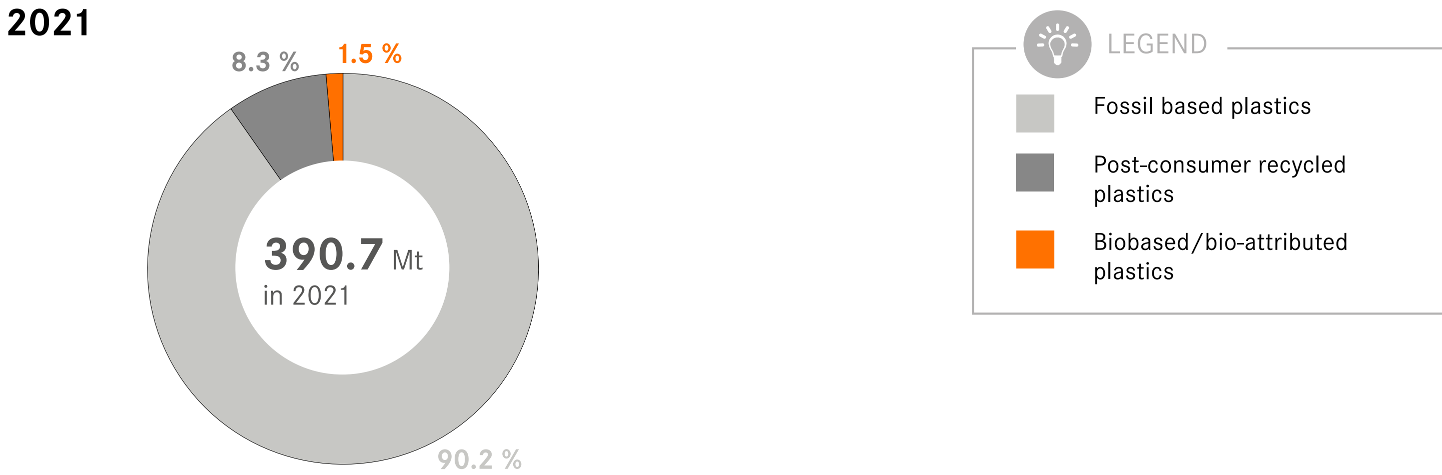


Figure 2: Global plastics production and distribution according to the three main sources of supply for plastics production in 2021[3]

Figure 2 shows three sources of supply for plastics: plastics based on fossil resources, the reuse of recycled materials and biobased raw materials. We can see that more than 90 % of global plastics production is based on fossil resources. These resources are, however, not only finite but also contribute to climate change through the release of fossil CO_2. A resource-efficient alternative to this is the reuse of recycled materials, which gives the highly valuable material plastic a second life. The proportion however, approx. 8 % of global plastic production, is still low.

The third and thus far least used source of supply for plastic products are biobased raw materials. Biobased (or also renewable) refers to raw materials of plant or animal origin that can be harvested after no more than two growth periods[4]. This distinction is important as fossil raw materials also have a biological origin. Over the course of several million years, these biological primary materials were converted into products such as petroleum or natural gas. As a result, the carbon contained in it had long disappeared from the earth's atmosphere – if you release it, this now increases the CO_2 content of the air. The carbon in renewable raw materials, on the other hand, was only absorbed from the air comparatively recently via plant photosynthesis. This means a closed CO_2 cycle.

3 Plastics – The Facts 2022. Plastics Europe, available under Plastics - The Facts 2022 • Plastics Europe,
4 ENDRES, H. J.; SIEBERT-RATHS, A. ENDRES, H. J.; SIEBERT-RATHS, A. Technical bio-polymers: framework conditions, market situation, manufacture, structure and properties. Carl Hanser Verlag, 2009.

3. TYPES OF (BIO-)PLASTICS

In contrast to the current negative image of plastics promoted by NGOs such as Greenpeace in striking campaigns[5], the term "bioplastic" always has positive connotations. The description „bioplastic“ is not clearly defined however, but is at best limited by two fundamentally different material properties:

- biobased and
- biodegradable.

Since these two properties can be both complementary and mutually exclusive, this classification results in four types of plastics (in contrast to the classification shown in **Figure 2** only by source of supply) (see **Figure 3**).

Figure 3 at bottom left (quadrant 3) shows so-called conventional plastics. These plastics are synthesised from petroleum-based/fossil based chemicals by chemically linking many small monomer units to long polymer chains. These plastics usually have a long durability, as their chemical bonds cannot be biodegraded by natural processes. They include the currently predominant mass plastics such as Polyethylene (PE) and Polypropylene (PP), as well as the technical plastics Polyvinyl chloride (PVC) and Polyamide (PA, "nylon"). They are inexpensive and available in large quantities.

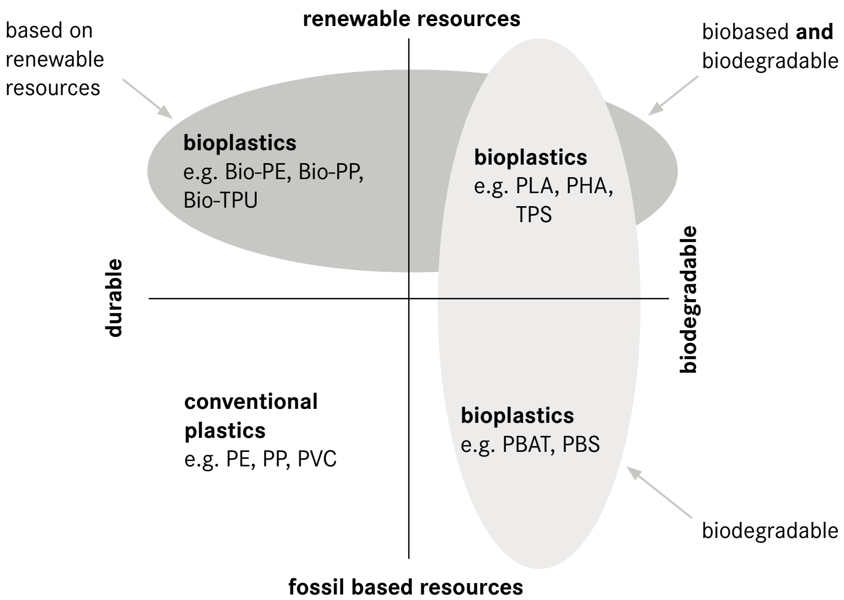


Figure 3: Classification of plastics

5 Climate Killer Plastic | Greenpeace

Other plastics are produced in the same way on the basis of fossil raw materials, but whose molecular bonds can be broken up by the metabolic processes of certain bacteria (**Figure 3**, bottom right, quadrant 4). They are biodegradable under suitable conditions and are therefore considered bioplastics. Representatives are, for example, Polybutylene adipate terephthalate (PBAT) or Polybutylene succinate (PBS). They can be used in mulch films for the agricultural sector or in compostable bags for household bio-waste.

The biobased plastics are shown in the upper half (rectangle 1 and 2) of **Figure 2.** A distinction is made between biodegradable and non-biodegradable (durable). Biobased and biodegradable plastics (quadrant 2) combine both properties that can qualify them as a bio-plastic. These materials have been known for a long time but have little industrial use. Polylactide (PLA) has now become well known due to the widespread use of 3D printing for private use, while other representatives such as Polyhydroxybutyrate (PHB) or Thermoplastic starch (TPS) are much less common.

The biodegradability of plastic products must be looked at differentiated. In certain outdoor applications, it can be advantageous if the component is likely to remain in the environment and should decompose without any residues. This can be intentional, as in the case of tree protection for young seedlings, or unintentional, for example, due to unavoidable abrasion on street sweepers.[6] In technical applications, however, a high level of durability and therefore a long service life are generally desirable.

In this case, biobased, but non-biodegradable plastics may be a solution, which can be found in quadrant 1 (top left). Their long-term resistance does not differ from conventional plastics, but they achieve a closed CO_2 cycle through the use of renewable resources. These plastics may be novel polymers such as Polyethylene furanoate (PEF). Materials that are chemically identical to the known conventional materials, however, can also be produced based on biobased chemicals, such as bioethanol. This type of plastics is known as “drop-in”[7] and offers the major advantage that the biobased counterparts require only minor adjustments to be processed in the established systems.

6 BioSinn - Products for which biodegradation makes sense (PDF) | Renewable Carbon Publications (renewable-carbon.eu)
7 Expert Council on Bioeconomics in Bavaria. Focal Topic: Drop-in Bioplastics. 2017

4. PRODUCTION AND RAW MATERIALS OF BIOBASED PLASTICS

The possible sources of biobased plastics are as diverse as their number. Some polymers are even found in nature. There are bacteria and algae that store excess energy by producing high-energy polymers directly in their cells. In times of shortage, these energy storage materials can be broken down into small building blocks and the energy can be recovered. This process can also be implemented in large-scale technology using fermentation.

In most cases, however, not the polymers as a whole are produced using biological processes, but rather the starting materials required for this process. A clear example of this is Polyethylene (PE): PE is synthesised in large-scale methods using suitable catalysts from ethene (ethylene gas). Ethene is a by-product of the cracking of natural gas and is therefore fossil-based. Ethene can also be produced from bioethanol, however, and therefore from renewable sources. If we use this biobased ethene as a raw material for PE production, we obtain bio-PE, which is chemically completely identical to conventional PE.

At the beginning of such a multi-stage production chain are high-carbohydrate building blocks such as sugar or starch or oily substances such as rapeseed or sunflower oil. These substances are referred to as first-generation biobased raw materials, as they can also be used for feed and food production. Discussions often arise about a possible competitive situation between food and plastics. In 2022, an estimated 0.015 % of available arable land worldwide (cf. **Figure 4**) was used for the production of biobased plastics and thus less than 0.01 % of the global agricultural area (cf. **Figure 4**).

EXCURSUS: POLYMER OR PLASTIC?

The chemical term “polymer” refers to highly molecular compounds made of hydrocarbons that are constructed from several thousand to several million small repeating units (monomers). A polymer in its pure form must be treated with suitable additives, which means that a plastic is a technically usable material made of polymers and additives. In German language usage, the term “Plastik” has a negative image and is avoided by professionals.

Land use estimation for bioplastics 2022 and 2027

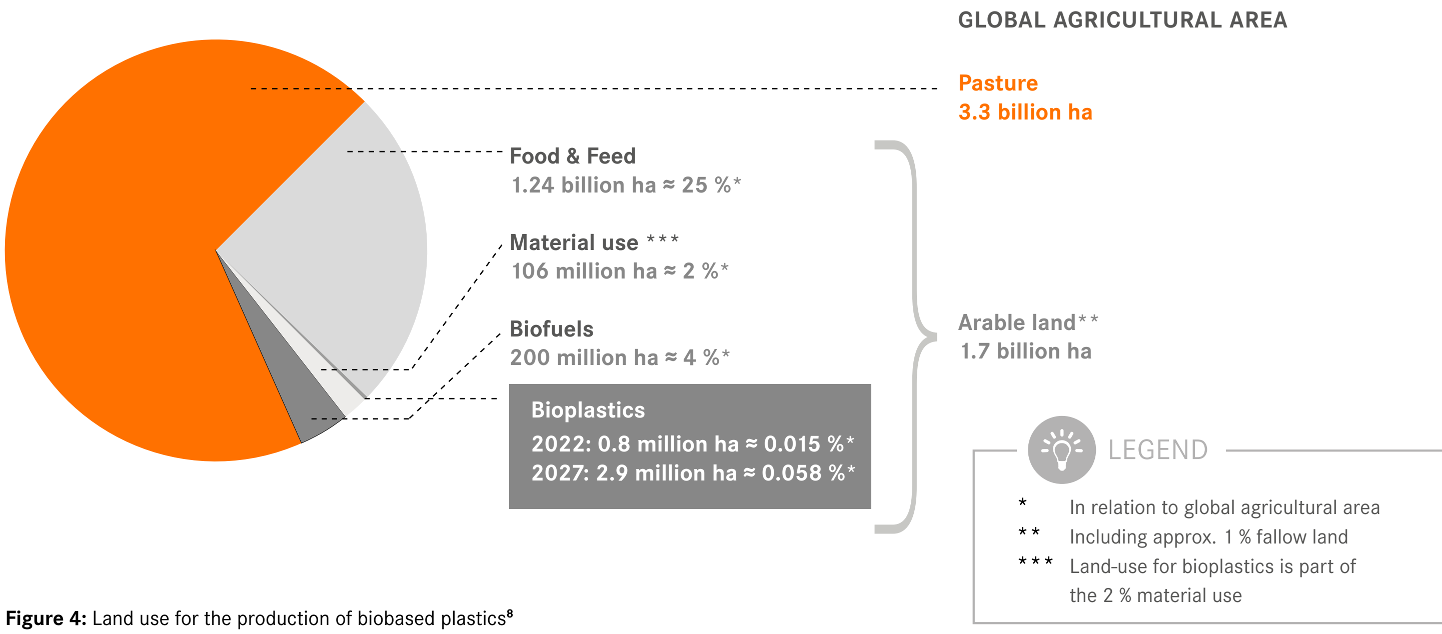


Figure 4: Land use for the production of biobased plastics[8]

For the future, the hope is that, with rising production volume and market share, the efficiency of the processes can be further improved, and the space required reduced. A major topic of research is currently the use of waste streams for the production of biobased plastics. These streams do not just consist of biowaste collected from households[9], but also residual materials from the agricultural industry. There are research approaches to the recovery of whey from the dairy industry or the straw produced during the grain harvest[10]. This process would result in significant savings in resources and emissions compared to conventional plastics.

5. LIMITS FOR THE PRODUCTION OF BIOBASED PLASTICS

So far, however, not all chemical building blocks are available on a biological basis. This means that biobased and conventional based chemicals can be used in the same step in polymer synthesis. In this case, we talk about partially biobased or bio-attributed plastics. For the purpose of calculating, the proportion of biobased starting materials is allocated to the produced polymer (cf. **Figure 5**).

8 Feedstock – European Bioplastics e.V. (european-bioplastics.org)
9 Biowaste to products (BW2Pro) - Biopro BW (bio-pro.de)
10 „Green“ Ethyl Acetate from Whey – How It Works (ingenieur.de); Old Grease Becomes High-Tech Plastic (covestro.com) BluCon Biotech: New Bioplastic Made of Straw (plasticker.de)

For partially biobased plastics, a detailed look at the composition is important, which can easily be explained by the example of PVC. Although it is now possible to produce a partially biobased PVC with certain basic building blocks[11], biobased additives are also used in the processing of conventional PVC into processable plastic. As a result, the plastic is considered to be partially biobased, even though the PVC contained in it was produced entirely on the basis of fossil raw materials. Conversely, however, not all the additives needed to produce high-quality types of plastics can be produced from renewable raw materials. As a result, mixing a biobased plastic with fossil-based additives is currently not uncommon.

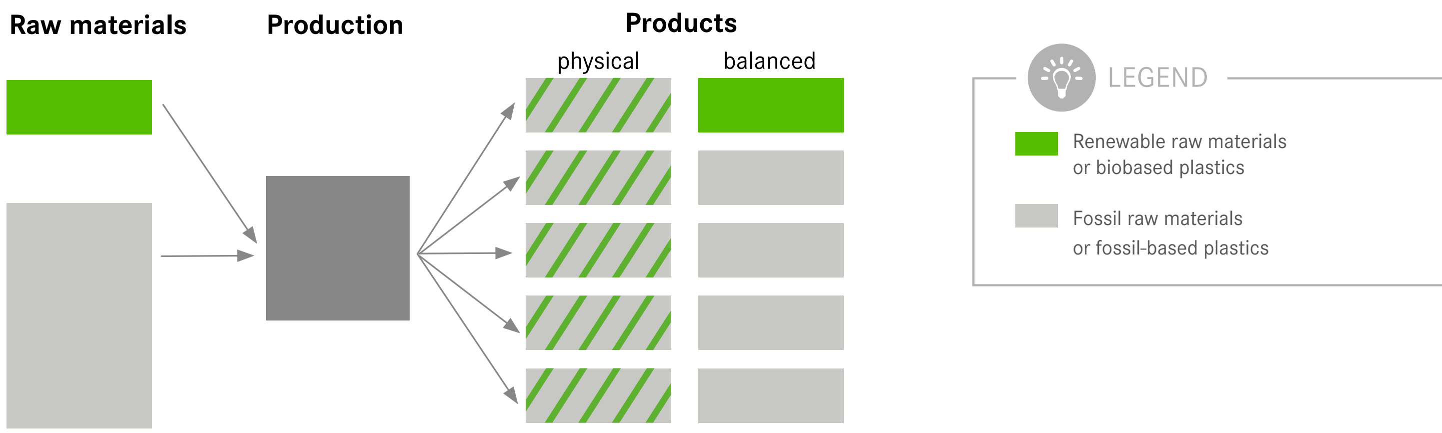


Figure 5: Calculation of the bio-content in partially biobased plastics[12]

The C14 methods allows the precise determination of the amount of biobased raw materials in a product. In all living organisms, the radioactive isotope C14 occurs in a fixed proportion. As the organism dies, the decay is no longer compensated and therefore the concentration of C14 is continuously decreasing. By determining the active C14 in a substance, the proportion of young or regenerating carbon can therefore be precisely determined[13].

In addition to this clearly assignable organic content, renewable raw materials are also used at other points along the long process chain from polymer to plastic. These can be used in energy generation or at geographically separate locations within the company. In these cases, a so-called mass balance[14] can be carried out, certifiable in accordance with ISO 22095:2020. This is a purely mathematical method; the biomass content cannot necessarily be verified in the product in question.

11 Westlake Vinnolit | GreenVin PVC bio-attributed
12 FNR - Biofuels: Mass Balance
13 OK biobased (tuv-at.be)
14 Mass_Balance_Approach_Renewable_Feedstocks.pdf

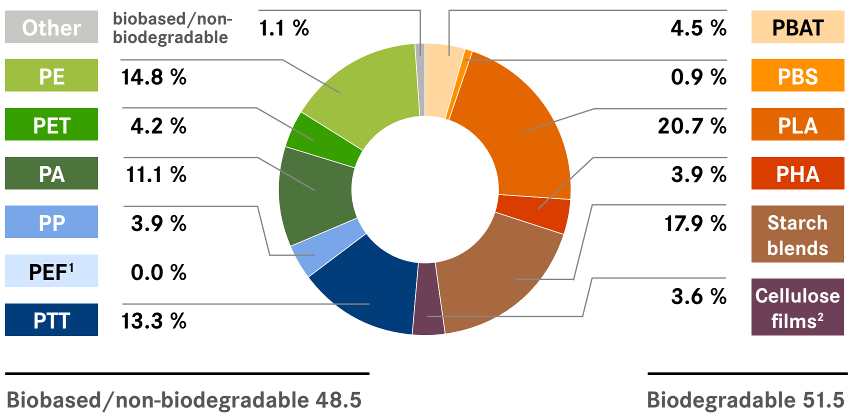
6. EXAMPLES OF BIOBASED PLASTICS

In 2022, more than 2 million tonnes of plastics were produced (see **Figure 6**). They are distributed almost equally between biodegradable and durable bioplastics. The products are usually clearly visible to the private end consumer, and their launch on the market is often accompanied by major advertising campaigns.

Under the slogan „Plants from plants," LEGO® has announced that all LEGO® components that represent plants will be produced from biobased plastic in the future.[14] These components are made of Polyethylene (PE) (**Figure 6**) which, with 14.8 % market share, plays a major role among biobased plastics in the industry. The Coca-Cola Company, on the other hand, is presenting the first prototype of a 100 % biobased PET bottle. Until now, only partially biobased PET has been available in the industry, as only one of the two basic building blocks of PET could be produced using renewable raw materials. In the development stage, a new solution could be found for the second monomer.[15] There are now countless examples of biobased products in the consumer sector. They range from bio-waste bags and coffee capsules, through catering utensils and gym shoes, to mobile phone housings and children's toys.

The situation is different in the technical field. Not only is the production of a component demanding, but there are also high requirements for its service life. High temperatures occur in the engine compartment of a car for instance and impurities from motor oil or petrol can also occur. Biobased plastics can also offer alternatives here,

Global production capacities of bioplastics 2022
(by material type)



[1]PEF is currently in development and not yet commercially available. [2]Regenerated cellulose films

Figure 6: Bioplastics production capacities worldwide in 2022[16]

14 Story: Plants from Plants - About Us - LEGO.com
15 Bottles Made From 100% Plant Plastic | The Coca-Cola Company
16 Materials – European Bioplastics e.V. (european-bioplastics.org)

however, whether for an engine compartment cover made of biobased Polyamide or for rawl plugs made of partially biobased plastics.

LAPP too, a leading supplier of integrated solutions and branded products in the field of cable and connection technology, is working on expanding its product portfolio and is looking for sustainable materials. In collaboration with BASF, an ETHERLINE® cable (data cable for ETHERNET-based communications) has been developed by the company that uses BASF's biobased plastic compounds as jacket material. This is a partially biobased Thermoplastic polyurethane (TPU) that is made up of up to 60 % of renewable raw materials. The type used at LAPP has been proven to contain 43 % renewable carbon[17]. The cable meets all requirements in terms of mechanical properties, processability and long-term resistance, just like the previous product from the portfolio.

7. CONCLUSION

Biobased plastics still account for the smallest proportion of the plastics produced worldwide. Partly for good reasons: the raw materials used for this obviously should not lead to a lack of resources elsewhere, especially when it comes to feeding people and animals. At the same time, approaches to using bio-residue mass as a raw material, e.g. from agricultural waste, are potentially promising – and an excellent example of the necessary development towards a circular economy.

Existing products made of biobased plastics, such as the Ethernet cable from LAPP, show that they not only have ecological advantages, but are also in no way inferior to conventional plastic products in terms of their material and utilisation properties. In a future in which mankind will have to continue to reduce the consumption of finite resources and the emission of greenhouse gases, biobased plastics will be an essential factor in the economy and society, given the central importance of plastics.

More research and cost reductions as part of stronger adaptation by companies and the resulting scaling and optimisation effects could soon contribute to a much larger proportion of biobased plastics – a development that cannot take off early enough from an ecological point of view.

17 Tested according to ASTM D6866