Why are biobased and biodegradable plastic not part of the solution to reduce plastic waste?

Checking the facts!

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List of Abbreviations

1,4-BDO	1,4-butanediol
ASEAN	Associations of South-East Asian Nations
ASTM	Australian Standards
Bio-PE	Biobased polyethylene
CAP SEA	Collaborative Actions for Single Use Plastic prevention in South East Asia
EN	European Norm
EPS	Extended Polystyrene
EPU	Economic Planning Unit (Malaysia)
HDPE	High density polyethylene
ID	Indonesia
ISCC	International Sustainability and Carbon Certification
ISO	International Organisation for Standardisation
LCA	Life cycle assessment
LDPE	Low density polyethylene
LUC	Land Use Change
MOEF	Ministry of Environment and Forestry (Indonesia)
MY	Malaysia
PA	Polyamide
PBAT	Polybutylene adipate terephthalate
PBS	Polybutyl succinate
PCD	pollution control department (Thailand)
PCL	Polycaprolactone
PE	Polyethylene
PET / rPET	(recycled) Polyethylene terephthalate
PFAS	Polyfluorinated alkyl substances
PHA	Polyhydroxyalcanoates
PLA	Polylactic acid
PP	Polypropylene
PPWD	Packaging and Packaging Waste Directive (Directive 94/62/EC 1994)
PS	Polystyrene
PUR	Polyurethane
PVA	Polyvinyl alcohol
PVC	Polyvinyl chloride
PVDC	Polyvinylidene chloride
RSB	Roundtable on Sustainable Biomaterials
SA	Succinic acid
SAN	Sustainable Agriculture Network of the Rainforest Alliance Certification System
SIRIM	Standard and Industrial Research Institute of Malaysia under the Ministry of International Trade and Industry (MITI)
SUP	Single-use plastic
SUPD	Single-use plastic Directive (Directive (EU) 2019/904 2019)
TH	Thailand
TPS	Thermoplastic starch
TISI	Thai Industrial Standards Institute
WFD	Waste Framework Directive (Directive 2008/98/EC 2008)

The seven most important facts and related explanations in short! (Executive Summary)

	Facts	Short explanation
1	Referring to plastics, "biobased" is a synonym for the term "made from natural origin" or "made from natural raw materials". These materials are agricultural products such as corn, tapioca, bamboo, sugarcane, potato or palm leaves; or agricultural waste. Furthermore, "biobased" does not always mean that 100 % of the raw materials are renewable.	In contrast, conventional plastic is fossil-based, i.e. made from crude oil. Combinations of biobased and fossil-based feedstock are commonly used. Anyway, such combinations are referred to as "biobased". They may neither be compostable nor recyclable, Different types of biobased plastics are suitable for making different consumer products, e.g. food containers or organic waste collection bags. **Read more in chapter 2.1**
2	Based on life cycle assessment, the substitution of fossil-based plastic with biobased plastic does not result in a significant improvement for the environment. Instead, the impacts shift. Biobased plastics have a lower impact on climate change but a higher potential for eutrophication. Moreover, they consume larger areas of land. Biobased plastic is only recommended if fabricated based on agricultural waste.	In addition, the LCA assessment methodology underestimates systematically and leaves aside impacts on biodiversity (land use change, monoculture). This also holds true for problems associated with leaching of hazardous substances, littering and microplastic which cannot be assessed through LCA. The recommendation to prefer renewable resources based on agricultural waste is based on the understanding that eatable agricultural products should serve as nutrition first. **Read more in chapter 4.1.1**
3	Two types of biodegradability of plastics can be distinguished: industrial vs. home/ambient compostable plastic. In ambient composting, biodegradable consumer products and packaging de facto do not degrade completely and not as quickly as in industrial composting plants.	In an organic waste treatment plant, the degradability environment can be adjusted in technical terms as regards air supply (or not), number and type of microbiotic population, pH etc. In nature, conditions are less stable as in treatment plants and differ for different soils, freshwater or marine water systems. The number of biodegradable plastics that degrade under ambient conditions in different environments is very limited. A PHA film, for example, degrades by ~70 % in 660 days in soil whereas PCL degrades in freshwater by over 90% in 30 days. Rather, mechanical disintegration takes place in the meantime, e.g. in the sand or by salt (in marine water). This leads to fragmentation and, thus, microplastic formation. **Read more in chapter 2.2**
4	The use of biomass feedstocks does not necessarily mean that the finished product will be biodegradable, even if the raw material is biodegradable.	Biodegradability does not depend on the raw material, but purely on the chemical structure of the polymer. Only some chemical bonds can be broken down biologically, i.e. enzymatically and microbiologically. There are examples of biobased, non-biodegradable plastics as well as examples of fossil-based, biodegradable plastics. **Read more in chapter 2.2**
5	There are standards available for industrial biodegradability of plastics as well as third-party certification for degradation in several ambient environments. Standards also exist as to the share, origin and sustainable cultivation of biomass in a biobased polymer.	Standards are an important instrument. However, they should not be considered the only answer to the problems associated with bioplastics: It is for example difficult to distinguish third-party certifications from company-specific or self-declared claims about biodegradebility. **Read more in chapter 3**

	Facts	Short explanation
6	The EU has acknowledged the importance of mandatorily regulating biobased and biodegradable plastic and is working towards the development of a respective legislation.	The European Commission announced a dedicated policy framework on the sourcing, labelling and use of biobased plastics, and the use of biodegradable and compostable plastics. The proposal is expected to be published in the course of 2021. **Read more in chapter 5.3.**
7	Biobased and biodegradable plastic is often promoted as a solution to problems associated with the amount of plastic waste, also in South-East Asia. At present, however, it does not reduce the existing waste volumes nor problems associated with solid waste management.	In theory, degradability is more favourable than recycling which, in turn, is more favourable than disposal. In practice, this presumes the separate sorting and collection of biodegradable and non-degradable plastics. Complexity for sorting processes would increase in view of the fact that some biobased plastics pose difficulties in recycling facilities for conventional plastic. Moreover, some other specific biobased and conventional plastics with the same chemical structure can be recycled together. Furthermore, biodegradable material would need to be transported to industrial composting facilities. In consequence, these would need to adjust their processes, e.g. with regard to composting. This requires more time for biodegradable plastic than for organic waste. Another prerequisite is that the material meets the requirements for industrial composting according to one of the biodegradability standards. Malaysia lacks industrial composting plants in general. In Thailand, the only industrial composting plant of the country is located in Bangkok. Most countries worldwide do not have adequate separation schemes for organic (wet) and dry household waste. **Read more in chapter 4.1.2 and chapter 5.**

The five most important To Dos:

1. In waste management projects, prioritize waste prevention over promotion of biodegradable and biobased plastic, e.g. through reuse. Biodegradable and biobased plastics should not be considered a solution to the problem of plastic pollution.

2. Use certified biodegradable food waste bags to separate wet and dry solid waste. For example, Typ-I ecolabelled food waste bags or other reliable, independent, third-party schemes can be used. No other use of biodegradable plastic is recommended. Thus, do not incentivize the use of biobased and biodegradable plastic.

3. Use only agricultural waste and by-products as raw materials for biobased plastics.

4. Create the necessary transparency and clearly communicate to the public through standards, labels and testing whether the relevant material is designed for biodegradation in industrial composting facilities, home composting or composting in the natural environment.

5. Invest in source segregation, sorting technologies and organic waste management facilities.

1 Background

Disposable, single-use packaging is convenient from the perspective of consumers. This holds true, for example, for take-away food packaging. However, the high amounts of plastic consumed entail various negative impacts. In the dilemma between ecological perspectives on single-use plastic and the convenience that this type of plastic packaging offers, biobased and biodegradable plastic have been discussed as an alternative to fossil-based plastics for quite some time. Environmental benefits are often attributed to biobased and biodegradable plastic, the reason being that "bio" is understood to mean "environmentally friendly". They are perceived as suitable substitutes for the conventional plastics whose environmental impacts have been widely researched. However, this supposed solution implies various consequences and problems. A one-to-one substitution of conventional plastic with biodegradable or biobased plastic is too narrow. Neither does it lead to any changes in waste volumes nor to a reduction of the associated environmental impacts in the long run. The background and reasoning of this assessment and analysis is part of the following report.

This report has been prepared by Oeko-Institut, Germany. The target audience of this report are the political decision-makers and companies in Thailand, Malaysia, and Indonesia. Currently, the target audience in the abovementioned countries are supported by the GIZ project module CAP SEA (Collaborative Action for Single-Use Plastic Prevention in Southeast Asia). The CAP SEA project aims to reduce plastic waste and to promote reusable packaging systems in Thailand, Malaysia, and Indonesia. This will be done by focussing on upstream approaches and embedding them in a broader context of circular economy, providing strategic advice to the government.

CAP SEA is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). It is part of the global project to support the "Export Initiative for Green Technologies". GIZ is the main implementer, the implementation period running from August 2019 to March 2023.

This report has been prepared to provide simple assistance to CAP SEA partner organisations in their work. Science-based background knowledge on biobased and biodegradable plastic shall enable the partners to avoid regrettable substitution by substituting one single-use alternative. Conventional single-use plastic items and packaging might be replaced by biobased or biodegradable variations, for example. This paper aims to raise awareness for the need to consider the trade-offs in this context. Furthermore, it is to anticipate consequences of material decisions in terms of environmental impacts and end-of-life treatment.

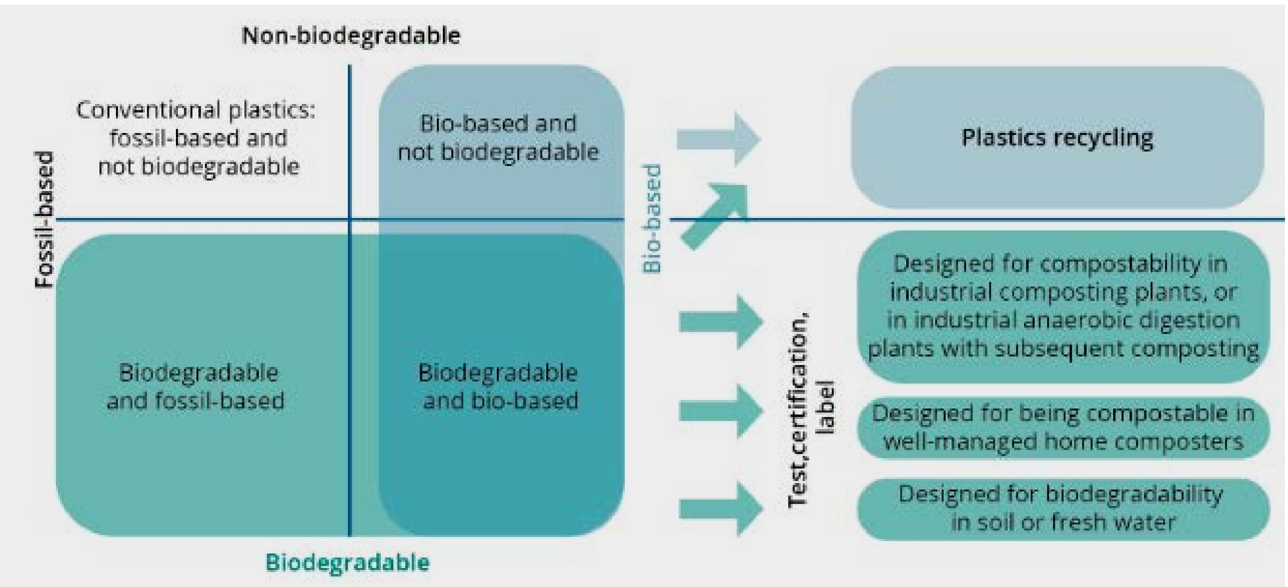
2 Understanding different types of bioplastic

The term *bioplastics* covers two different characteristic features of a plastic material: One is the origin of the input into the plastic production, in this case the *bio-* refers to *biobased*. The other relates to degradability characteristics of the plastic at the end-of-life stage; in that case, *bio-* refers to *biodegradability*. The term *bioplastics* is often used inconsistently in the sense that it sometimes describes both characteristics of a material – the material's natural origin and biodegradability. In other contexts, bioplastic only refers to one of the two aspects.

Compostability and *biodegradability*, or rather *compostable* and *biodegradable*, are as well used inconsistently. In most cases, and so in this report if not stated differently, biodegradability of plastics refers to industrially compostable plastics.

Thus, first, we provide a glossary and an explanatory figure (Figure 2-1) of the European Environment Agency (2020). Figure 21 describes the four possible combinations of the two characteristics (material's origin & degradability) in a matrix on the left-hand side. On the right-hand side, the figure already indicates the end-of-life routes which the materials can follow depending on the respective characteristics.

Figure 2-1: Different categories of biodegradable and biobased plastics.



Source: (EEA 2020)

- "**Biobased plastics** are fully or partly made from biological raw materials as opposed to the fossil raw material (oil) used in conventional plastics" (the so-called fossil-based plastic).

- **Biodegradable plastic** can be produced from either biobased or fossil-based raw materials. Biodegradable plastic "is designed to biodegrade in a specific medium under respective conditions (water, soil, compost, etc.)". Respectively, two types of biodegradability can be distinguished:
  - "*Industrially compostable* plastics are designed to biodegrade in the conditions of an industrial composting plant or an industrial anaerobic digestion plant with a subsequent composting step."
  - Second, "*home/ambient compostable* plastics which are designed to biodegrade in the conditions of a well-managed home composter or in open environments" (mainly, this means at lower temperatures than in industrial composting plants).

- A minor group is called **oxo-degradable plastics**. These types of plastic "include additives that, through oxidation, lead to the material's fragmentation into microplastics or chemical degradation."

Each of the following chapters focuses on one of the two aspects of bioplastics.

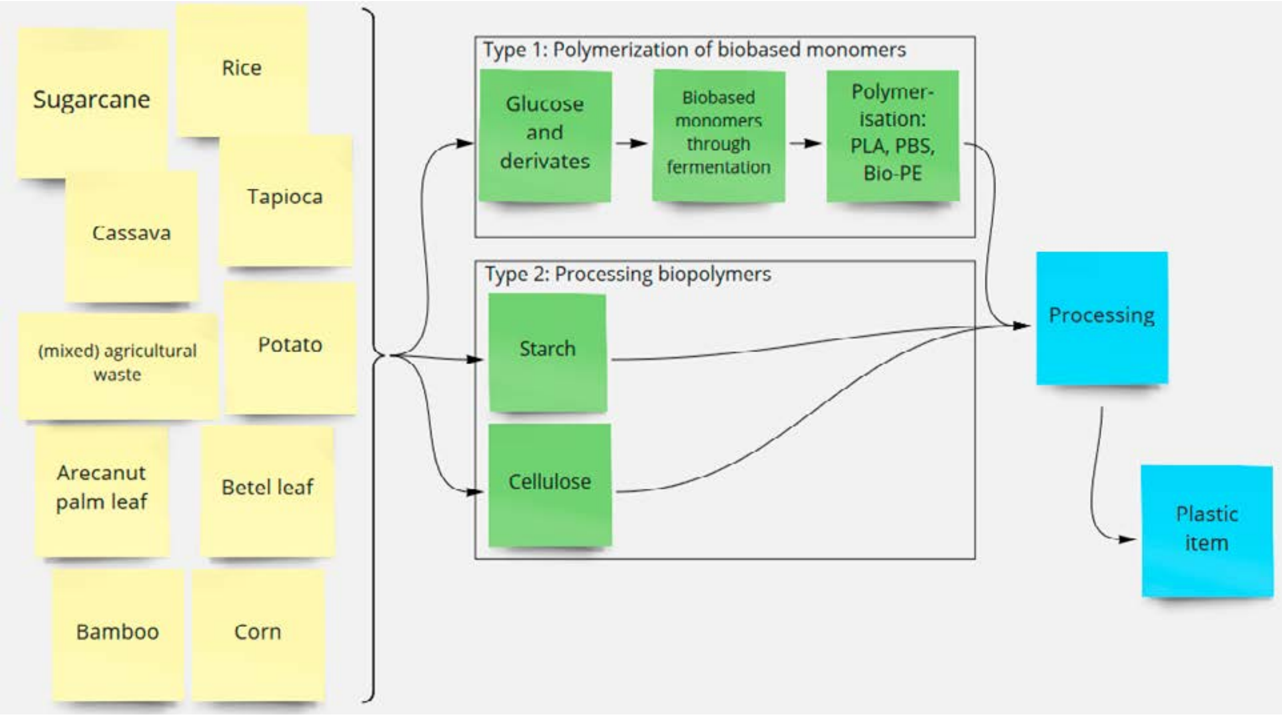
2.1 Biobased material

Biobased plastics partly or completely originate from natural raw materials. Therefore, the term *from renewable raw materials* is used synonymously with biobased. In the European context, the term biobased is used in accordance with the definition of biobased products set out in EN 16575:2014. The raw materials are starch- or cellulose-rich plants such as corn, sugarcane, miscanthus (a certain sweet grass) and sometimes wood. In contrast to biobased raw materials, conventional plastics are fossil-based. They are extracted from crude oil. *Biobased* does not always mean that 100 % of the raw materials are renewable. Biobased plastics can also be used in a composite also containing petroleum-based plastics. Percentages may not always be clearly communicated to consumers (see also chapter 3).

In Europe, biobased plastics are most frequently used in food packaging (52 % or 1.26 Mt of the total biobased plastics market in 2019). They are also used in other sectors, including textiles (10 %), consumer goods (10 %), automotive (7 %), agriculture (7 %), coating and adhesives (7 %), construction (4 %), and others (3 %) (Brizga et al. 2020).

Different biobased polymer types are fabricated in different ways according to the (bio-)chemical structure of the raw material.

Figure 2-2: Overview: From plants to polymers



Source: Own illustration.

Based on the information from Letcher (2020), two types of manufacturing processes for biobased material can be distinguished:

- **Polymerization of biobased monomers** (e.g. polylactic acid (PLA), polybutyl succinate (PBS), Bio-polyethylene (Bio-PE); type 1 in Figure 2-2) and,
- **Processing of biopolymers** (e.g. lignin, proteins, rubber, cellulose, and starch; type 2 in Figure 2-2).

The term *polymer* relates to the fact that plastic is made up of long chains ("poly" = many) of the so-called monomers that are chemically bound to each other. Several substances can be used as monomers, e.g. lactic acid, ethylene, or glucose (and many more), provided that their chemical structure allows for at least two different types of chemical reaction with another molecule of the same substance to form the chain.

With regards to the two different types of manufacturing of biobased plastics and most important representatives in each category, Letcher (2020) further explains:

The most important polymers obtained through the **polymerization of biobased monomers** are PLA, PBS and Bio-PE (i.e. drop-in-plastics, see explanation below). Once the polymer is obtained, the technical processing into plastic items is the same as for fossil-based thermoplastics such as PET, PE, etc. However, they do not have the same chemical structure as the fossil-based thermoplastics monomers differ from each other.

- **PLA** is obtained by polymerization of lactic acid which is generated through the fermentation of carbohydrates, mainly starch e.g. from corn, cassava or agricultural waste. Theoretically, lactic acid could also be produced from fossil resources. However, this is not a common practice.

- **PBS** is a co-polymer based on monomers succinic acid (SA) and 1,4-butanediol (1,4-BDO). The monomers are obtained by fermentation from carbohydrate sources, mostly sugars (BASF 2021). However, both monomers (succinic acid and 1,4-butanediol) can also be fossil-based. An advantage of PBS is its easy processability, e.g. injection molding, extrusion, and film blowing, using conventional equipment and its good mechanical properties, e.g. resistance, hardness/ strength, or elasticity.

- **Drop-in-plastics** are traditional polymer types such as polyethylene (PE), polyethylene terephthalate (PET), polyamides (PA) based on monomers from natural origin. Polyethylene, for example, is produced by polymerizing ethylene gas. This gas can be produced from crude oil or, as in the case of biodiesel, from bioethanol. Thus, Bio-PE is polyethylene which is 100 % based on bioethanol. At the time of publication, there is only one production plant worldwide for Bio-PE (in Brazil), which produces bioethanol from sugarcane.

From the category of **biopolymers**, cellulose and starch are the most important (and most common) ones to produce biobased plastics.

- **Cellulose**, e.g. from bamboo, cannot be processed as a thermoplastic without modification. This is only possible via a specific solution method or after derivatization – a reaction between the hydroxyl groups in the cellulose structure with a certain reacting molecule which consequently changes the molecules characteristics. This allows the molecule to undergo higher temperatures during thermal processing. Without the derivatization, the cellulose would easily degrade at elevated temperatures. The cellulose-based plastics are biodegradable provided that the reactants are biodegradable.

- **Starch**, e.g. from potato, tapioca, too, is not suitable to be processed as a thermoplastic. It is either chemically modified to become thermoplastic starch (TPS), or it is used in a blend, the so-called starch blends.
  - Pure TPS is very sensitive to humidity, thus it is not suitable for most polymer applications.
  - In starch blends, starch functions as a filler in either biobased, mainly PLA-based, or fossil-based plastics. However, combining starch and PLA is still at the research stage. However, starch blends with fossil-based plastics with starch contents above 50 % are the most common type of starch-based biopolymers. Only if starch blends contain 100 % biodegradable components, i.e. no blends with non-biodegradable fossil-based polymers, the starch polymers are biodegradable. In practice, for starch blends, this composition is very rare. At present, it is best to assume that starch blends are not biodegradable.

- **PHA** (polyhydroxyalcanoates) are of additional interest. This biopolymer is synthesized by several hundreds of bacteria as an intracellular product. In contrast to cellulose or starch, PHAs are processable like conventional thermoplastics through injection molding or extrusion.

2.2 Biodegradable plastic

Biodegradable plastic can be based on natural raw materials such as starch, cellulose, or carbohydrates, e.g. obtained from potato, cassava, etc. However, some fossil-based plastics are biodegradable too. Thus, it is not true that all biodegradable plastics are biobased (see Table 2.1).

Typical applications of biodegradable plastics include:

- Packaging, e.g. take away food packaging, pouches, netting, trays etc., for fruit, vegetables, eggs and fresh meat;
- Catering products, if separately collected from other plastic waste, they can be (industrially) composted together with any remaining food after use;
- Waste bags to collect organic waste as well as shopping bags;
- Biodegradable mulch films; and
- Medical applications.

"Biodegradable plastics are mainly designed to biodegrade under specific conditions – most commonly in an industrial composting facility in which temperatures exceed 50 °C for extended periods of weeks or months" (Letcher 2020). Therefore, **industrial and home compostable plastic** can be distinguished from each other on the basis of different reaction conditions (i.e., temperature, composition of microorganisms, presence of oxygen, etc.) in a controlled (industrial) vs. un-controlled (natural) environment.

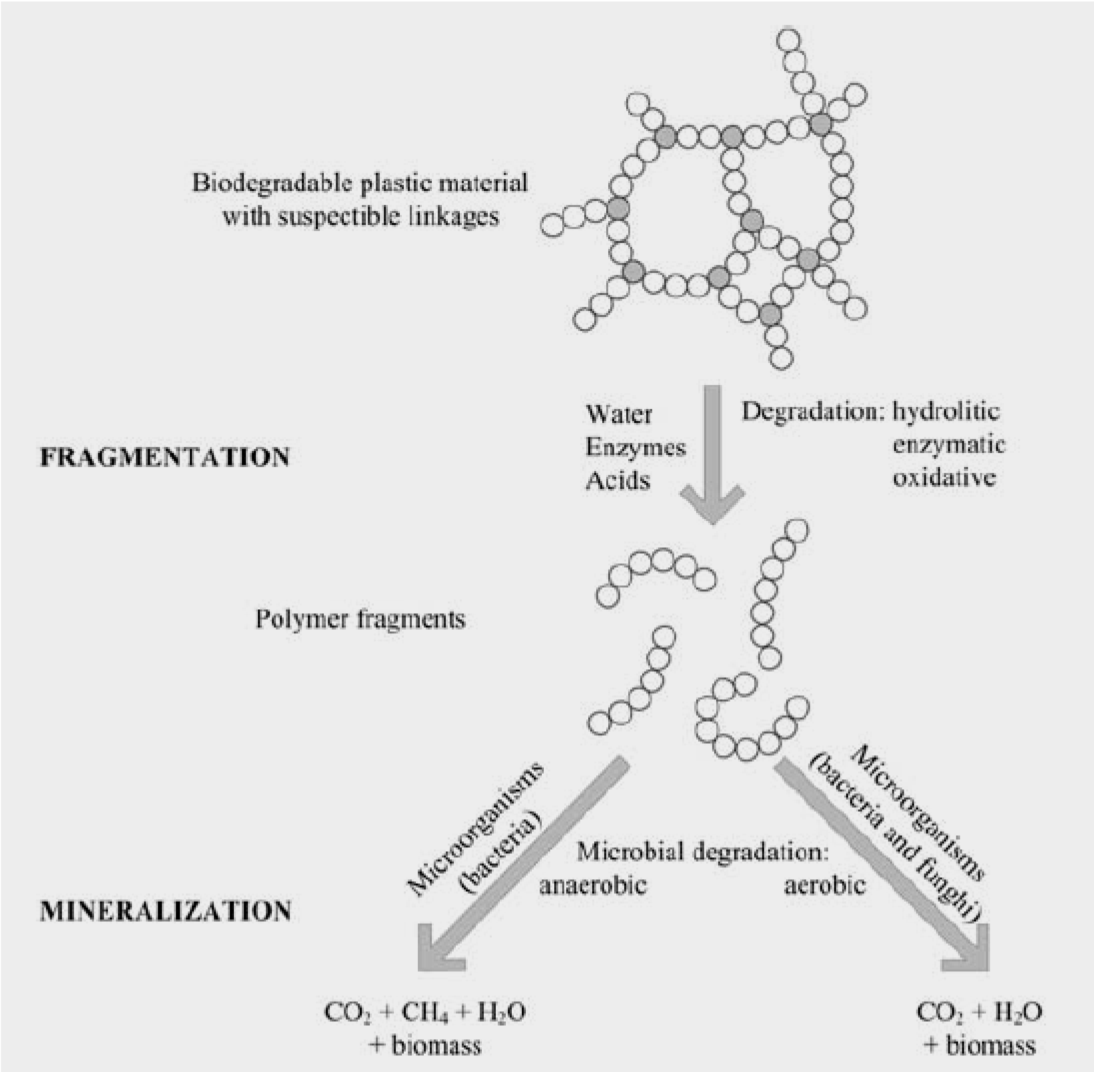
Generally speaking, the biodegradability process of a polymer is the sequence of a fragmentation, followed by the mineralisation of the fragments. In the first stage, some chemical bonds in the polymer chain break under the influence of heat, moisture, sunlight, and/or enzymes, resulting in shorter polymer chains (fragmentation). Second, the plastic fragments are completely deconstructed by microorganisms in, e.g. aerobic or anaerobic, soil or marine conditions. These (disposal) environments differ in the set of microorganisms that are able to break down the polymer fragments (mineralisation). Both steps, fragmentation and mineralisation, are a prerequisite for a plastic to be biodegradable, see Figure 2-3. (Letcher 2020)

Table 2.1: Distinguishing biodegradable and non-biodegradable plastic based on raw materials' origin

	Biodegradable*	Non-biodegradable
Biobased plastics	PLA, PHA, PBS, cellulose-, lignin- and starch-based plastics (incl. TPS) and blends, if free from non-degradable ingredients & additives	Drop-in-plastics, e.g. Bio-PE, Bio-PET, Bio-PA etc.
Fossil-based plastic	PBS, polyvinyl alcohol (PVA), polycaprolactone (PCL), polybutylenadipate terephthalate (PBAT) etc.	PE, PP, PET, PS, PVC, PA, PUR, others.
Notes: * biodegradable in industrial composting		

Source: adapted from Brizga et al. 2020

Figure 2-3: Biodegradation process of polymers



Source: Letcher 2020

As already mentioned, as for the mineralization, microorganisms are capable of breaking the chemical bonds under two regimes: Either an aerobic, i.e. oxygen-rich, or an anaerobic, i.e. oxygen-free, regime. These two degradation routes not only differ in the oxygen content available to the microorganisms, but also in the type of microorganisms and the degradation products. In simple terms, biodegradable material chemically mainly consists of C-, H- and O-atoms[1]. If enough atmospheric oxygen (O_2) is available during the reaction (aerobic regime), the material will react to form CO_2 and H_2O. Due to the absence of oxygen (O_2) in anaerobic digestion processes, not all C- and H-atoms "find enough O-atoms" to form CO_2 and H_2O. Instead, they combine and form CH_4, methane. The microorganisms play a catalytic role, thus, initiate and facilitate the reaction (energetically).

When transferring the micro level of chemical reactions to the natural environment, one realizes that it is a more complex system, as there are various types of soil and aquifers. The number and composition of microorganisms, the environmental conditions (e.g. temperature, O_2 levels, pH value or types of nutrient present) and finally water solubility of the polymers play an important role for degradation. It should be noted that aerobic conditions can be expected in the majority of soils, while in water, either aerobic or anaerobic conditions may prevail dependent on the depth of water and light incidence (Umweltbundesamt 2018).

Authors of the same report (Umweltbundesamt 2018) researched and compiled the technical literature (Table 2.2), concluding that the time of biodegradation strongly depends on the environmental conditions[2]: Polylactic acid (PLA) degradation time is 6-9 weeks in industrial composting, but is not found to be degradable in soil, freshwater or seawater. TPS and PCL, to name two other examples, degrade in approx. 50 days in industrial composting plants and freshwater. However, it takes several months for them to degrade in soil and seawater. According to the authors, TPS, PCL and PHA are degradable under anaerobic conditions, PLA only at temperatures > 50 °C. Co-polyesters such as PBS and PBAT are not anaerobically degradable (Umweltbundesamt 2018).

Additional information regarding biodegradability in the open environment can be found in a report from the Science Advice for Policy by European Academics (SAPEA 2020).

Table 2.2: Degradation time of biodegradable polymers

Biodegradability in different environments	**Approximate degradation time of various polymers**					
	TPS	**PHA**	**PCL**	**PLA**	**PBAT**	**PBS**
Biodegradable under conditions of industrial composting (58 ± 2 °C)	1-1,5 months	1-1,5 months	1-1,5 months	~2 months	~2 months	~5 months
Biodegradable in soil (20-28 °C)	7-12 months	7-12 months	7-12 months	> 1 **year**	7-12 months	Not spec.
Biodegradable in fresh water (20-25 °C)	< 2 months	< 2 months	< 2 months	> 1,5 **years**	> 1,5 **years**	3 months
Biodegradable in seawater (30 °C)	< 6 months	< 6 months	< 6 months	> 1,5 **years**	> 1,5 **years**	Not spec.
Note: More detailed figures are shown in Table A1 (page 41).						

Source: Umweltbundesamt 2018

1 The difference of oxygen atoms (-O-) bound in the polymer structure and oxygen (O2) in the atmosphere of the reaction chamber is relevant from a chemical point of view.

2 Sampling sites of studies evaluated included various regions incl. Vietnam, China, South & Central Europe, the USA and Australia.

In an organic waste treatment plant, it is possible to technologically define the degradability environment, i.e. to adjust the conditions for anaerobic or aerobic degradation. Examples are air supply (or not), number and type of microbiotic population and pH. In the case of prevailing aerobic conditions, the term 'industrial composting plant' is used, while, in the case of prevailing anaerobic conditions, the relevant plant is referred to as 'industrial anaerobic digestion plant'. The degradation degree and the time that various biodegradable polymers are subject to aerobic industrial composting for specific durations are shown in Table 2.2 and Table A-1 (a).

It is important to note that biodegradability does not depend on the raw material, but solely on the chemical structure of the end product. Only some chemical bonds can be broken down biologically, i.e. enzymatically and microbiologically. The use of bio-mass feedstocks does not necessarily mean that the finished product will be biodegradable, even if this is the case for its raw material. For example, drop-in-plastics like Bio-PE are biobased, but non-biodegradable (e.g.). In contrast, fossil-based plastics such as polycaprolactone (PCL) or polyvinyl alcohol (PVA) are biodegradable. Examples for each of the four combinations are given in the matrix in Figure 2-1.

In theory, degradability is more favourable than recycling which, in turn, is more favourable than disposal. In practice, this presumes the separate sorting and collection of biodegradable and non-degradable plastics. Complexity for sorting processes would increase in light of the facts that some biobased plastics pose difficulties in recycling facilities of conventional plastic, and that some other specific biobased and conventional plastics with the same chemical structure can be recycled together. Furthermore, biodegradable material would need to be transported to industrial composting facilities. In consequence, these would need to adjust their processes. Composting times, for example, are longer for biodegradable plastic than for organic waste. Another prerequisite is that the material meets the requirements for industrial composting according to one of the biodegradability standards (see chapter 3).

In the context of biodegradable plastic, the so-called **oxo-degradable plastic** is often mentioned. However, "oxo-degradable plastic is conventional fossil-based polymers (such as PE, PP, PS etc.) to which an additive (usually an inorganic compound) has been added which accelerated the polymer degradation when exposed to heat and/or light" (Letcher 2020). In the EU, the placing on the market of products made from oxo-degradable plastic is prohibited based on Art. 5 of the Single-Use Plastic Directive (Directive (EU) 2019/904 2019). Oxo-degradable plastics do not meet the requirements for industrial and/or home composting set out in different standards. Through mechanical abrasion, such plastic quickly disintegrates into small pieces which belong to the group of microplastics. However, this type of plastic does not disintegrate completely (no mineralization). The microplastic particles of oxo-degradable plastic remain in the environment. Such material is not suitable for effective long-term reuse or for mechanical recycling, because the additives contribute to a rapid loss of mechanical properties (Aldas et al. 2018).

3 Standards & Certification

Standards and certification for biobased raw materials

A biobased polymer product can be certified in two complementary ways, firstly with regard to the actual use of biomass relating to the share of renewable resources, and secondly with regard to the conditions under which the biomass was grown. Thus, two different types of certification can be distinguished: (a) the certification of the usage of renewable raw materials in the polymer on the one hand side, and (b) the certification for the cultivation and origin of the biomass used based on sustainability criteria on the other side.

As already mentioned in chapter 2.1, *biobased* does not always mean that 100 % of the raw materials are renewable. Biobased plastics can also be used in a mixture with petroleum-based plastics. The third-party verification scheme by DINCERTCO, for instance, offers certification of biobased plastic according to CEN/TS 16137[3], ISO 16620[4], and EN 16785-1[5]. Within this scheme, companies can verify minimum shares of biobased material of 20 %, 50 % or 85 % (DINCERTCO 2021). A comparable certification scheme exists in Belgium (TÜV Austria Belgium 2021), called OK biobased, whereas the BioPreferred Programm initiated by the US Department of Agriculture is applied in the USA (see Figure 3-1).

Figure 3-1: Certification schemes for biobased plastic products

Source: TÜV Austria Belgium 2021; DINCERTCO 2021; US Department of Agricuture 2021

3 CEN/TS 16137 "Plastics – Determination of bio-based carbon content"

4 ISO 16620 "Plastics – Biobased content"

5 EN 16785-1 "Bio-based products – Bio-based content – Part 1: Determination of the bio-based content using the radiocarbon analysis and elemental analysis"

Percentages may not always be clearly displayed and comprehensible to consumers. Rather, consumers do not know about the shortcomings of e. g. a 20 % certification (refer to chapter 4.1.1). The German Environment Agency (Umweltbundesamt 2017) concludes that the ecological signifycance of a certification for biobased products is limited, among other things since no distinction is made between different types of renewable raw materials or their geographical origin. To encounter this challenge, certification for cultivation and origin of biomass is an option: In order to compare various certificates available for biobased materials, a study for the German Environment Agency (Umweltbundesamt 2019) investigated their suitability for reliable certification of natural raw materials in German Ecolabels, the Blue Angel. Against this study's criteria which shall ensure a high level of environmental protection considering the high ambition of the Blue Angel, the certificate of the RSB (Roundtable on Sustainable Biomaterials) is recommended without restriction for all products. The certification systems ISCC[6] Plus can be referred to unobjectionable in the Blue Angel for five years from 2019. After that it shall be assessed whether an update of ISCC Plus criteria still meets the study's high criteria for environmental protection. In contrast, neither Bonsucro, REDcert (EU) and the SAN system (Sustainable Agriculture Network of the Rainforest Alliance Certification System) can be recommended for inclusion in the Blue Angel award criteria. These certification schemes cannot fulfill the study's verification criteria.

6 International Sustainability and Carbon Certification

Standards and certification for biodegradability.

Although standards and certification schemes do exist for biodegradability in industrial composting, only some countries such as Australia (AS 5810[7]) and France (NFT 51-800[8]) have a standard for home composting. There is also no international standard (i.e. ISO) specifying the conditions for home composting.

Amongst others, biodegradability standards for industrial composting and anaerobic digestion are given below. Find a list of most important standards in the Annex of this report (Table A-2). Biodegradation under anaerobic conditions is not yet required for certification but can optionally be determined.

- **Global**: ISO 18606 "Packaging and the environment. Organic recycling", ISO 17088 "Specifications for compostable plastics"
- **Europe**: EN 13432 "Packaging – requirements for packaging recoverable through composting and biodegradation. Test Scheme and evaluation criteria for the final acceptance of packaging", EN 14995 "Plastics – Evaluation of composability. Test scheme and specifications."
- **US**: ASTM D6400 "Standard specification for labelling of plastics designed to be aerobically composted in municipal or industrial facilities"
- **Australia**: AS 4736 "Biodegradable Plastic Suitable for Composting and other Microbial Treatment"

7 AS 5810 "Biodegradable plastic suitable for home composting"
8 NFT 51-800 "Specifications for plastics suitable for home composting"

These standards are quite similar to each other. Chemical characteristics of the material basis, biodegradation characteristics, disintegration and ecotoxicity requirements are the four main criteria within these industrial composting standards (Letcher 2020):

1. Chemical characteristics: "The product must contain at least 50 % organic matter and may not exceed several hazardous substance limits which vary between the different standards."

2. Biodegradation: "The product should biodegrade for at least 90 % within 6 months under controlled composting conditions." In this sense, 90 % of the carbon should be converted to CO_2.

3. Disintegration: Within 12 weeks, the fragment should disintegrate sufficiently to visually undetectable components under controlled composting conditions.

4. Ecotoxicity: The compost leaving the industrial composting should not pose a risk of causing any negative effects to the germination and growth of plants.

Besides the standards for biodegradable polymers in industrial composting, standards to assess the ambient degradability, i.e. in soil and water, also exist. They differ in the requirement in terms of time allowed for biodegradation of at least 90 % of the material (see Table 3.1).

Table 3.1: Comparison of standard requirements for different types of degradation

Objective of tests	Norm/Standard	Requirements on biodegradability
Industrial composting	EN 13432, ISO 17088*, EN 14995, ISO 18606*, ASTM D6400*, AS 4736	Minimum 90 % degradation after maximum **6 months**
Home composting	AS 5810, NF T 51-800	Minimum 90 % degradation after maximum **12 months**
Biodegradable in soil	EN 17033	Minimum 90 % degradation after maximum **24 months**
Biodegradable in freshwater	EN 13432, EN 14995, adapted to freshwater; EN 14987 (water soluble, dispersible polymers)	Minimum 90 % degradation after maximum **56 days**
Biodegradable in marine water	ASTM D7081	Minimum 90 % degradation after maximum **6 months**
* Separate testing of constituents if these weigh > 1 % by weight.		

Source: compiled by Umweltbundesamt 2018

Certain labels certify biodegradability based on one of the standards for biodegradable plastics, (see Figure 3-2).

An important example of the use of the biodegradability standards for polymers in Europe is the certification of biodegradable bags for the collection of organic/wet household waste. The legal situation for biodegradable organic waste bags varies in different EU member states: In Germany, for example, according to the Bio-waste Act, it is generally allowed to use biodegradable plastic bags for the collection of organic household waste, that are certified according to EN 14995 or EN 13432, and that are predominantly biobased. The rules stipulated on the municipal level, however, can be different, e.g. due to the absence of an industrial composting plant. The introduction of biodegradable plastic bags for organic waste collection together with the establishment of separate organic waste collection was a success story in Italy: 'A 2006 law ruled that compost has to be collected separately, either using bins or biodegradable bags. Since then, the amount collected has risen from 2 million tonnes to 4.2 million. The composters' association created a quality mark, and in 2013 78 % of high-quality compost was produced from waste collected by local governments' (Moffett 2013).

Figure 3-2: Biodegradability Certification

Industrial composting	INDUSTRIAL COMPOSTABLE DIN Geprüft	OK compost TÜV AUSTRIA INDUSTRIAL	BPI COMPOSTABLE IN INDUSTRIAL FACILITIES
Home composting	HOME COMPOSTABLE DIN Geprüft	HOME OK compost TÜV AUSTRIA HOME	
Biodegradability in natural compartments, e.g. soil and marine environment	BIODEGRADABLE IN SOIL DIN Geprüft	SOIL OK biodegradable TÜV AUSTRIA SOIL	MARINE OK biodegradable TÜV AUSTRIA MARINE

Source: TÜV Austria Belgium 2021; DINCERTCO 2021; Biodegradable Products Institute 2020

4 Evaluate the added value of biobased and biodegradable plastic

This chapter addresses the question of the added value associated with biobased and biodegradable plastic. Furthermore, the waste treatment options are highlighted in relation to impacts of the use of such material from three different perspectives: An environmental perspective, a consumer perspective, and an end-of-life management perspective. These perspectives present general reflections, while an additional country-specific perspective is given in chapter 5.

4.1 Environmental perspective

In the context of the environmental perspective on biobased and biodegradable plastic, two different questions are addressed:

1. What are the environmental impacts of materials of biobased compared to fossil-based plastics?
2. Which environmental benefit does a biodegradable material provide at the end of its life?

It is important to note that all questions on environmental impacts or advantages can only be answered in the domestic context. End-of-life options for biobased and bio-degradable plastic strongly depend on the sorting, collection and availability of recycling and industrial composting plants in a country-specific context. In addition, the land use and land use changes associated with the growing and farming of biobased material depend on general agricultural approaches. In some regions, monocultural farming might be a common practice for some plant species, e.g. wheat or palms. In contrast, artisanal agricultural practices might be applied for vegetables, incl. tapioca and potato. In another region, however, the typical agricultural goods and practices are different.

In addition to the two following subchapters, Oeko-Institut's Pre-Study on LCA-based material choices provide additional information (GIZ and Oeko-Institut e.V. 2021b).

4.1.1 Environmental impacts of biobased material

Biobased plastics are not more sustainable than conventional plastics: The substitution of fossil-based plastic with biobased plastic does not result in a significant improvement for the environment; instead, the impacts shift: Ita-Nagy et al. (2020) analysed a number of Life Cycle Assessment (LCA) studies that compared biobased and fossil-based plastics. The authors conclude that "bioplastics generally show lower climate change impact than fossil-based plastics [...]. However, these materials also show higher burdens in environmental categories related to harvesting and cultivation of the raw biomaterials, including LCA categories associated with water, such as eutrophication, and air, such as stratospheric ozone depletion or photochemical ozone formation."

Usually, the LCA is a well-acknowledged methodology in order to assess environmental impacts amongst policy makers. The assessment of the benefits and risks associated with the use of biobased plastics is complex, and LCAs only cover part of the situation. Three additional problems with regards to the material basis are:

- Due to challenges in modeling, **land use change** (LUC)[9] is an LCA category that has only been assessed to a minor extent. Piemonte and Gironi (2011) however 'highlight the strong influence of the LUC emissions on the global warming potential (GWP) of biobased materials.' The same authors point out 'the importance of using waste biomass or biomass grown on degraded and abandoned agricultural lands to produce bioplastics that, in this manner, can offer immediate and sustained GWP advantages.'

- It is comprehensible that a discussion similar to the long-standing debate on "food or fuel", is going on with regard to **land use conflicts**, i.e. whether land is used to grow food or biomass, and whether the grown food, e.g. tapioca, is used for plastic production instead of nutrition. These reflections are of relevance against the background of SDG 2 – zero hunger – and food security debates.

- The authors of the impact assessment study for biobased material (European Commission 2018b) acknowledge that 'high yield of crops in Brazil and the US are a result of large-scale **monoculture** depending on genetically modified organisms (GMO) breeds with other adverse impacts which are not included in the LCA for methodological and data availability reasons.' In short, it can be concluded that monocultural cultivation including the uses of GMO breeds, fertilizers and pesticides results in losses of biodiversity which is generally difficult to assess quantitatively.

In this sense, as concluded by Piemonte and Gironi (2011), plastic from agricultural waste, e.g. bagasse, palm leaves, mixed agricultural waste, should be preferred over biobased material that could be used as food.

Figure 4-1 (page 22) compares different polymers with regards to Global Warming Potential (A), Land Use (B) and Water Use (C) for the production (of polymer resins) of conventional versus biobased polymers based on a study presented by Brizga et al. (2020). Most of the conventional plastics (PUR, PA, PVC, PS, PET, HDPE, LDPE; and PP) have a lower impact on land and water use as can be seen from (B). This is due to the fossil fuel refineries' low impact on land and water use. The impact depends on the polymer-specific wet-chemical processes applied, e.g. for PUR and PA polymerization processes, water use is slightly higher than for other polymers. Comparing different types of biobased plastics, it is observed that drop-in-plastics ('Bio-xxx') have greater impacts in terms of land and water use than cellulose-based, starch-based, PBS and PBAT plastics. Considering the error bars, PLA and PHA are in a range comparable to that of drop-in-plastics. Thus, impacts on land and water use are independent from the type of manufacturing of biobased plastics as outlined in chapter 2.1 (polymerization of biobased monomers, including drop-in-plastics as well as PBS and PLA, and processing of biopolymers, including cellulose- and starch-based polymers). In terms of CO_2 emissions, the impacts of conventional plastics are higher than that of biobased plastics. As regards biobased plastics, wide error bars indicate a high variety of findings in the LCA studies evaluated for this meta-study. It is assumed that the differences originate from the origin of raw materials, transport distances, the type of manufacturing, and underlying assumptions.

In absolute figures, globally, around 170 Mt of plastic is used for packaging purposes annually (making up 44 % of global plastic consumption). The substitution of these petrochemical plastics with biobased plastics would require 613 Mt of corn (54 % of the current global production),

9 The EU Renewable Energy Directive (RED) defines direct land use change as "arising when the produc-tion of feedstock has led to a change from one of the following land covers: forest land, grassland, wet-lands, settlements, or other land, to cropland or perennial cropland". Indirect land use change is defined as follows: "Where pasture or agricultural land previously destined for food and feed markets is diverted to biofuel production, the non-fuel demand will still need to be satisfied either through intensification of current production or by bringing non-agricultural land into production elsewhere. The latter case constitutes indirect land-use change […]".cited in European Commission (2018b).

1.8 Mt of castor beans (12 times of the current global production), and 21.3 Mt of wood (around 0.8 % of the current global roundwood production). In order to satisfy these land-based inputs, a minimum of 61 million ha of land (which is larger than the total area of Thailand) and at least 388.8 billion m^3 of water (60 % more than the EU's annual freshwater withdrawal) would be required. (Brizga et al. 2020)

A study performed for the European Commission (2018b) evaluated key environmental hotspots of biobased plastics and compared these impacts with fossil fuel-based counterparts. Seven case studies on beverage bottles, horticultural clips (excluded in Table 4.1) for the reason of low applicability), single-use drinking cups, single-use carrier bags, food packaging films, single-use cutlery, and agricultural mulch films were included in the study. Table 4.1 gives an overview of the case studies' findings. Generally, it was found, that over the course of their life (from feedstock production to end-of-life), 30-60 % of the total environmental impacts of biobased products can be attributed to climate change, abiotic depletion (indicating the impacts associated with the extraction and consumption of resources) and human toxicity. These three impact categories are associated with high energy use and direct emissions at the end-of-life. While Brizga et al. focus on "production" in the sense of biomass production, the study for the European Commission found that 'amongst the five life cycle stages, i.e. from biomass production to end-of-life[10], the manufacturing of biobased polymers and fossil-fuel based copolymers as well as the plastic conversion step have the highest impacts'. This is because more energy is consumed for the industrial processes compared to biomass production.

Similar to other studies comparing products made from natural resources to that made of non-natural resources, the authors of the European Commission's report (2018b) highlight the shortcomings of the LCA carried out in the context of this assessment. The following aspects which are strongly influencing biodiversity and eco-toxicity are excluded due to limited information available:

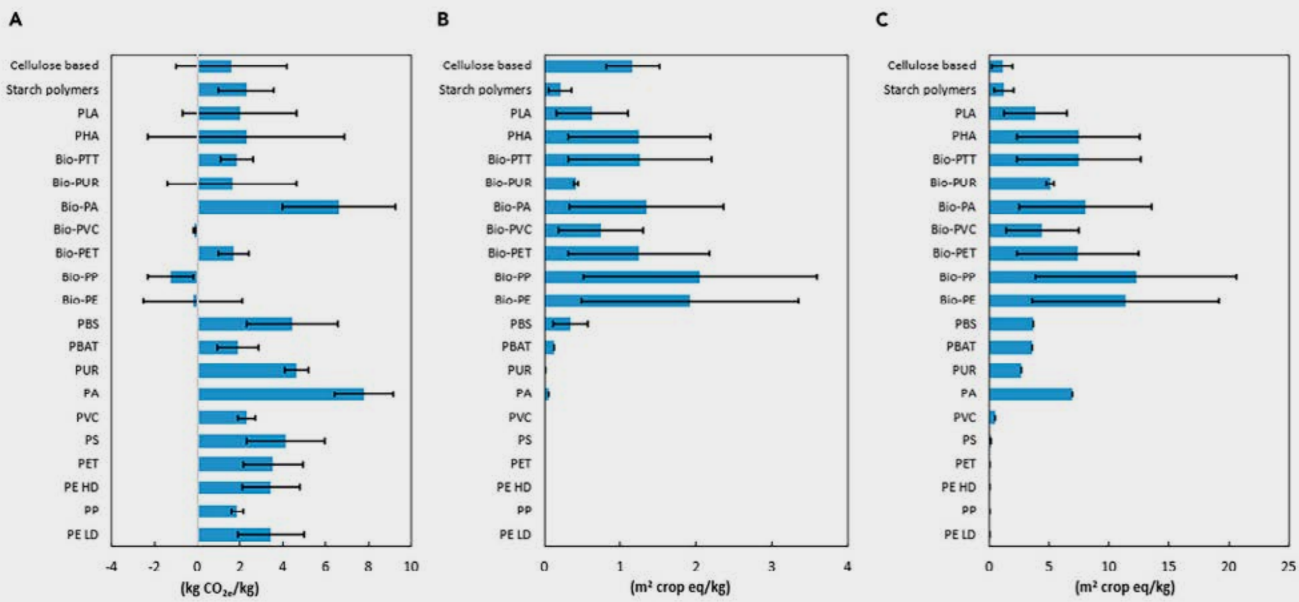
- Large-scale monoculture based on GMO breeds,
- indirect land use change,
- pesticides used,
- social conflicts associated to land use,
- impacts from littering, and
- impacts from microplastics[11].

The same study (European Commission 2018b) investigated two examples of waste feedstock instead of cultivated crops: (1) horticultural clips made from potato peels; and (2) biobased PP cups made from used cooking oils. On (1): A starch blend, i.e. a co-polymer of a fossil- and a biobased polymer are used to produce the horticultural clips. As the dominating environmental impacts can be attributed to the fossil-fuel based component, the benefits of reduced impacts from waste feedstock production are marginal. The authors highlight that 'more research and development into processing technology and materials is needed before significant improvements in environmental impacts can be achieved. On (2): 'Biobased PP made from used cooking oil offers lower global warming potential in comparison with the PLA cups. […] the benefits are derived from low impacts of raw feedstock and plastic conversion processes.' It has become clear that such materials, i.e. potato peel and cooking oil, cannot supply the global markets of today.

10 1 – biomass production; 2 – polymer production; 3 – plastics conversion; 4 – transportation; and 5 – end-of-life

11 Physical impacts from microplastic, e.g. entanglement; chemical impacts from microplastic, e.g. through un¬-known additives, and biological impacts of microplastic, e.g. carrier of germs.

Figure 4-1: Comparison of plastics with regards to Global Warming Potential (A), Land Use (B) and Water Use (C) for their production



Note: It is assumed that toxicity to humans and ecosystems is another relevant impact category for which insufficient data is available, thus it was excluded from the review.

Source: Brizga et al. 2020

Table 4.1: Environmental impact hotspots and comparison of biobased and fossil-fuel based polymers for six case studies

Case Study	Biobased polymer	Environmental impact hotspots for biobased polymer	Fossil fuel-based polymer	Comparison of biobased and fossil fuel-based polymers
Beverage bottles	30 % Bio-PET	The bottles show the strongest impacts in biomass production compared to other case studies. This is due to sugarcane harvesting in Brazil (28 % of cradle-to-grave impactsb). Polymerisation of ethylene glycol and terephthalic acid accounts for 50 % of the impacts. For both, Bio-PET and fossil fuel-based PET, recycling is the most favorable end-of-life technology.	PET	The use of biobased PET instead of fossil-based PET in beverage bottles leads to a reduction in global warming potential and fossil fuel consumption. However, it may increase water consumption and eutrophication (Benavides et al. 2018).
Single-use drinking cups	PLAa	The conversion from sugarcane or maize into polymer PLA has the predominant impact, accounting for 40-60 % of the process energy (for heating process water) and process chemicals used. Other relevant impacts are caused by the transporttation of PLA from Thailand to Europe. Due to low food-contamination (e.g. compared to food packaging films and cutlery), the impact reduction potential is greater for recycled PLA than for industrially composted PLA.	PET; PP	PLA cups and PLA-lined paper cups are not necessarily more environmentally friendly than fossil-based plastic options (OVAM 2006; Changwichan und Gheewala 2020). The potentially lower GWP of biobased polymers is accompanied by higher impacts in other impact categories such as acidification, eutrophication, and human toxicity (Harst et al. 2014).
Single-use carrier bags	Starch blend	The manufacturing of the starch blend (bio- and fossil-based co-polymer) accounts for 80 % of the impacts. Thereof, the impacts from the fossil fuel-based co-polymer are dominant. Industrial composting is the most favorable end-of-life option for carrier bags made from starch plastics if being fully biodegradable.	LDPE	A biobased (corn-based) single use shopping bag has higher GWP, acidification, and ozone pollution than a fossil-based single-use PP bag in Singapore(Khoo et al. 2010). The high energy demand in the production phase is the main reason for this effect.
Food packaging films	PLAa	See the single-use drinking cups, but higher food contamination. If industrial composting is implemented for all PLA food packaging films, the overall impacts decrease by 25 % or 30 % compared to incineration or landfilling.	PP	The electricity grid mix used to manufacture the food packaging affects its performance. PLA food packaging produced with the Thai electricity mix has higher GWP, acidifycation, and photochemical ozone formation compared to PS food packaging (Suwanmanee et al. 2013).
Single-use cutlery	PLAa	See food packaging films.	PS	[-]e
Agricultural mulch films	Starch blend	See single-use carrier bag. Here, however, in-situ soil degradation was assumed to be the most probable and also the intended end-of-life scenario. If recycling is assumed, the end-of-life impacts are highly sensitive to the assumed amount of soil that is collected together with the plastics.	LDPE	[-]e

(a) Based on Maize (US) and sugarcane (Thailand);

(b) The cradle-to-grave impacts cover five life cycle stages: Biomass production, polymer production, plastics conversion, transportation and end-of-life;

(c) Impacts are modeled for cradle-to-user, end-of-life and land use changes.

(d) Bio-PET is currently only available from Braskem (Brazil).

(e) Not looked into in detail.

Note: Impacts from littering, large-scale monoculture based on GMO breeds and indirect land use change are excluded due to limited available information.

Source: (European Commission 2018b; Benavides et al. 2018; Changwichan und Gheewala 2020; Harst et al. 2014; Khoo et al. 2010; OVAM 2006; Suwanmanee et al. 2013)

4.1.2 Environmental impacts of the end-of-life of degradable material

Biodegradable plastic is often promoted as a solution to problems associated with the amount of plastic waste. However, it is not able to reduce waste volumes and has limited possibilities to solve problems associated with solid waste management: While biodegradable waste bags for organic waste can support the separation of wet and dry waste, biobased and biodegradable plastic requires additional effort for sorting of plastic waste fractions for recycling. Biodegradable plastics have some distinct disadvantages (Brizga et al. 2020; Oakes 5 Nov 2019; EEA 2020; Umweltbundesamt 2018; DUH 2018a):

- The number of biodegradable plastics that degrade under ambient conditions in different environments, e.g. home composter, marine water, etc., is very limited (see Table 2.2 and Table A1). Furthermore, **biodegradable plastics need special treatment** to degrade within a reasonable timespan of up to 6 months in industrial composting). The time needed to degrade is longer than that needed for other organic waste. This results in management problems for composting plant operators (DUH 2018b). In addition, degradation does not yield any humus.

- **In recycling processes**, biodegradable polymers are **incompatible with many other polymers** (e.g. polyolefines and PET). This causes problems for recycling operators because the presence of biodegradable polymers in the recycling feedstock acts as a pollutant and lowers the quality of recycled polymers (see chapter 0).

- The term “biodegradable” gives the general impression that plastic can be completely degraded – which is not true. Thus, there is a risk that consumers carelessly leave plastic in the open environment, leading to **littering**, and **microplastic distribution**.

- The stability of non-biodegradable plastic offers the possibility to reuse the material several times after recycling. This is an ecological advantage over biodegradable plastic which – through initial biological degradation reactions – loses material by weight and value.

- As most of the biodegradable plastic is biobased, environmental impacts associated with biobased material also play a role for biodegradable plastics.

In the long term, “their [biodegradable plastic] efficacy in providing an environmentally sound solution to solid waste accumulation will depend on the co-emergence of affordable waste sorting technology and investments in organic waste handling facilities (compost and anaerobic digestion)” (Dilkes-Hoffman et al. 2019).

In the short term, biodegradable plastics can have advantages for specific applications such as for segregating food waste for composting. Here, biodegradable plastic bags may have advantages when used to boost source separation of wet waste (Oakes 5 Nov 2019). ‘An example of best practice is South Korea which has raised its food waste recycling rate from just two percent in 1995 to 95 percent. South Korea achieved this through a range of policy measures from a ban on sending food to landfills over setting up designated food waste collection buckets to obliging consumers to purchase biodegradable bags for food disposals’ (Kim 2019). Italy is another good example of using biodegradable bags to segregate food waste (Moffett 2013).

4.2 Consumer and health perspective

Many consumers struggle to understand environmental claims and labels and do not differentiate between independent, third-party labels and self-declared claims. The European Environment Agency (EEA 2020) concludes that "the differences between 'compostable in industrial composting plants', 'home compostable', 'biodegradable in soil/freshwater/marine water' and 'biobased' are not easy to understand". ECOS explains the reason for this phenomenon: "In absence of clear specific legislation on green claims, companies are free to use vague language […]. Green claims can even be used to circumvent legal product restrictions […]" (ECOS; Rethink Plastic; #breakfreefromplastic 2021)For example, according to a survey conducted in Germany, 58 % of respondents thought that all 'bioplastics' were compostable" (Blesin et al. 2017). The surveying of Consumers International and UNEP found out that labels and certificates do not always help consumers to make better informed purchasing decisions (UNEP 2020). To evaluate compostability, biodegradability and biobased content claims for packaging and products, ECOS et al. (2021) proposes a claims checklist (see Annex, Figure A-2),

Another problem arises due to the fact that not all the plastic which are communicated in advertising to be biodegradable is certified on the basis of the existing standards (Figure 3-2). As certification schemes test the material for the presence of hazardous additives added on grounds of enhanced processability, non-certified biodegradable plastic can be an entry route for such additives into the environment, if not disposed of correctly (through municipal solid waste).

As to the hazards of substances that are commonly associated with plastic packaging, Groh et al. (2019) found that 'of the 906 chemicals commonly associated with plastic packaging, 63 rank highest in terms of human health hazards and 68 in terms of environmental hazards[12]. Furthermore, 7 of the 906 substances are classified as persistent, bioaccumulative, and toxic (PBT) or very persistent and very bioaccumulative, and 35 as endocrine disrupting chemicals throughout the EU. It should be noted that some of the substances can be attributed to more than one group of hazards. Plastic packaging contains such substances whether or not it is made (partly) from recycled content or biobased material (Geueke et al. 2018; Zimmermann et al. 2020). Zimmermann et al. (2020) investigated biobased food-packaging, e.g. trays, coffee cups, tea bag wrapper. It was shown that these biobased products contain levels of chemicals similar to that of fossil-based plastics, including some with toxic properties. Strakova et al. (2021) found comparable results: "The highest concentrations [of polyfluorinated alkyl substances (PFAS)] were consistently found in moulded fibre products, such as bowls, plates, and food boxes advertised as biodegradable or compostable disposable products […]."

If the material degrades, such additives and their degradation products enter the biomass cycle. If the biomass is then used for agricultural purposes, hazardous additives and degradation products can cause harm to the environment and consumer health.

12 According to the harmonized hazard classifications based on the Nations' Globally Harmonized System (GHS)

4.3 End-of-life management perspective

Finally, this chapter addresses the question whether there are any preferences for biobased and biodegradable materials from an end-of-life perspective.

A convenient method for determining in which waste stream a material will end up is provided in Figure 4-2. Based on the main material of a product, the decision tree helps to identify the most probable end-of-life. This makes it possible to assess the added value of a material choice for certain disposal routes.

In a first step, the main material can be attributed to one of following three groups: conventional plastic, fibre carbohydrate feedstock and non-fibre carbohydrate feedstock. Different polymer types can be considered in a second step. Based on step 2, the typical end-of-life route can be identified as a result. Four different end-of-life routes are distinguished: Recycling, combustion, industrial composting and ambient/home composting. The thicker arrows in Figure 4-2 represent a higher likelihood for the respective option. In the light of the environmental and consumer perspective presented above, it can be concluded that ambient composting is highly dependent on the environment. Moreover, biobased and biodegradable plastic is currently not designed for ambient composting. Industrial composting is an option, only if a suitable plant is available (see domestic situations presented in chapter 5. Thus, the two most likely end-of-life scenarios are combustion and (mechanical) recycling. Recyclers of conventional plastics are not in favour of biodegradable plastics in their input stream. A biodegradable fraction in conventional plastic recyclates has a negative effect on the final properties such as strength and durability of a product in which the recyclate is used.

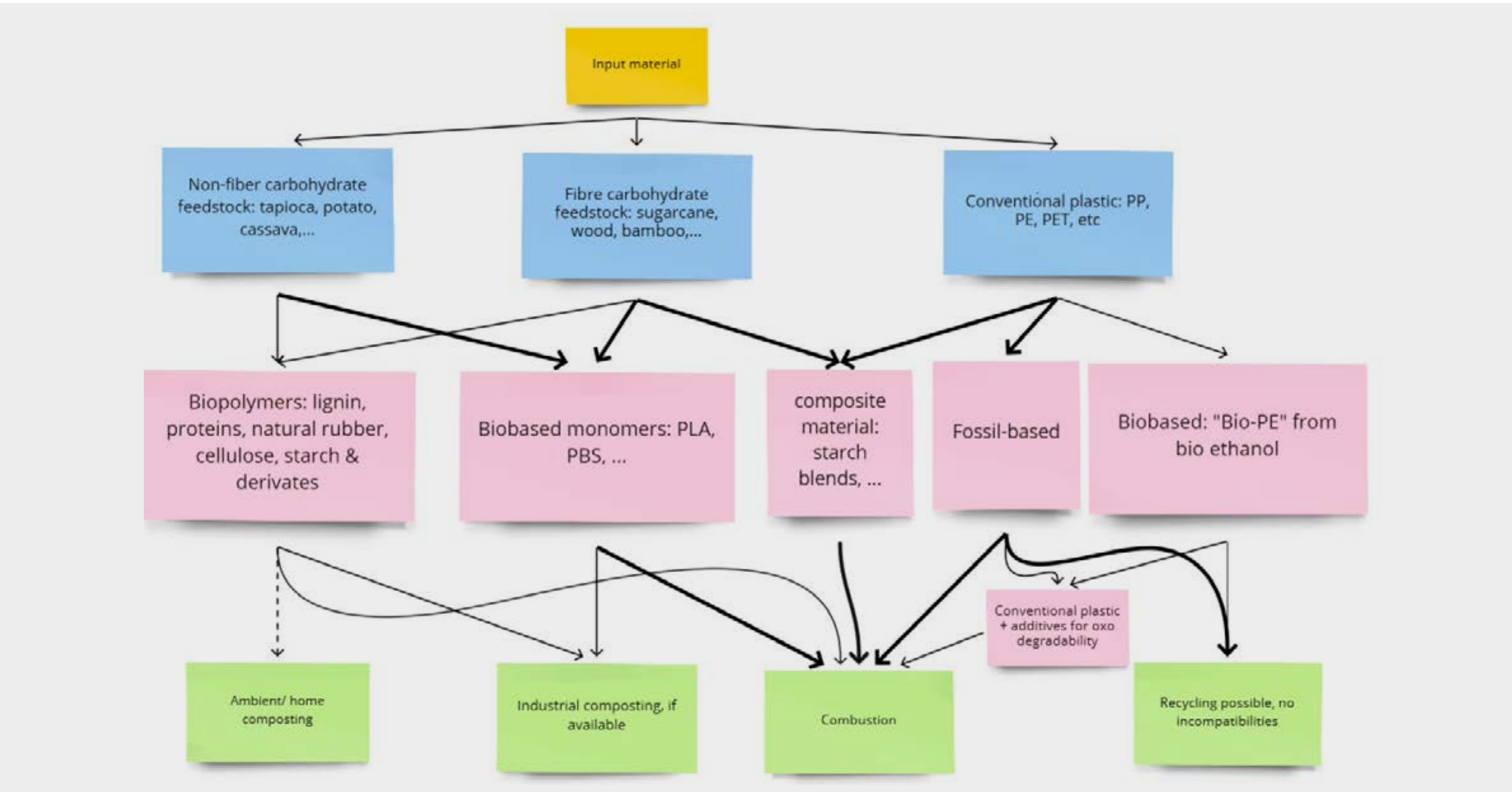
An example is PLA (already 0.1 %) in PET bottle recycling: Alaerts et al. (2018) explain that PLA and PET melt at different temperatures. When PET melts at 255 °C during mechanical recycling, the PLA fraction has already been above its melting point (155 °C) for a fairly long period of time. PLA already starts to degrade while PET is still in the melting process. As a consequence, the recyclate starts to turn yellow. As PLA and PET are not miscible in the solid state, flakes agglomerate and opaqueness or haziness occur when processing PET recyclate into pellets. For another biodegradable polymer, PHB (poly-3-hydroxybutyrate) which is the most common type of PHA polymers, Alaerts et al. conclude that 'if it [PHB] were to end up in the feed of rPET production (e.g., via the bottle fraction), similar issues as encountered for PLA with respect to the mechanical recycling of PET may occur'. The melting point of PHB is 180 °C (Alaerts et al. 2018).

The melting points of HDPE, LDPE and PP are 135 °C, 110 °C and 160 °C, respectively (Chemgapedia 2021). It is expected that the effect observed for PLA contamination in PET recyclates originating from the difference of melting points (Δ100 °C) is less likely for abovementioned polymers. This is supported by Åkesson (2021).[13] According to this study (Åkesson et al. 2021), the fact is expectable that PET is the most sensitive polymer to the effects of a small amount of TPS blends on the mechanical recycling. It is explained that polyester groups in the PET's backbone are sensitive to hydroxyl groups present in the TPS structure. The hydroxyl groups attack the chemical bonds in the PET structure which leads to PET degradation resulting in 'inferior mechanical properties'.

13 Authors found that 'the tensile strength and modulus of PE were relatively unaffected. However, elongation was significantly reduced. Adding 5 % TPS/PLA to HDPE reduced the elongation from about 1300 % to 150 %. PP was somewhat more sensitive than HDPE. This could be seen especially for the Charpy impact strength. Adding 5 % TPS/PLA to PP, the Charpy impact strength was reduced from roughly 56 to 21 kJ/m^2.' Tensile strength, modulus, elongation and Charpy impact strength are typical physical and mechanical properties of polymers of interest for processing the material.

Åkesson et al. conclude that, since there are many different polymers on the market, both fossil-based and biobased ones, it is difficult to determine the extent at which the introduction of biobased polymers threatens the mechanical recycling of conventional polymers. Secondary plastic is also contaminated by other conventional polymers which affect the mechanical and physical characteristics of the secondary resins, see Pre-Study on Recycled Content (GIZ and Oeko-Institut e.V. 2021a). It was not concluded that the contamination of biopolymer would lead to a substantial reduction of thermal and mechanical properties on the basis of the polymer's biodegradability alone.

Figure 4-2: Decision tree for end-of-life of different material types (higher likelihood for thicker arrows)



Source: Own graphic

5 Country-specific situation and developments

Whether or not biodegradable and biobased products entail advantages or pose any risks is linked to the country-specific situation of (plastic) waste management. Therefore, the domestic situation in the partner countries of the CAP SEA project is described in the following subchapters.

5.1 Malaysia

A recent study evaluated opportunities and barriers in the (circular) plastic market in Malaysia including the status quo for biobased and biodegradable plastic (World Bank Group 2021a).

The situation for biobased plastics in Malaysia is summarized in Table 5.1.

The World Bank report points out that 'bioplastics are likely to have a more important role in sustainable packaging sourcing decisions for major brand owners in Malaysia in the future' (World Bank Group 2021a).

As outlined earlier in this report, standardization and certification are key for ensuring biodegradability and preventing microplastics and hazardous substances entering organic waste streams and the ambient environment. In Malaysia, there are two sets of eco-labelling criteria (a) for biodegradable and compostable plastic and bioplastic packaging materials (ECO 001:2018), and (b) for biodegradable and compostable biomass-based products used for food contact application (ECO 009:2016). These criteria include environmental requirements. Thus a degradation test, for example, is intended to provide an indication of the potential of plastic to persist in the environment. Residuals are tested for their toxic metal content and the standard differentiates between ambient/home composting and industrial composting. Since the revision of the eco-labelling criteria in 2018, photo- and oxo-degradable plastic cannot obtain the eco-label anymore.

Table 5.1: Status Quo for biobased plastics in Malaysia

Local biobased resin production	up to 12,000 tons per year[14] led by Australian firm SECOS Group and SIRIM
Amount used domestically within Malaysia	10–20 % of the bioplastics resin produced in Malaysia is used domestically. The remaining share is exported to markets around the world including the United States, the EU, Japan, Korea and China
Applications	single use applications for packaging and/or food contact applications, e.g. beverage cups, straws, cutlery, tea bags, and carry bags; limited application in non-woven fabric market such as face masks

Source: (World Bank Group 2021a)

14 Malaysian plastic manufacturers produced 2.45 million tonnes of plastic resin, World Bank Group (2021a)

With regards to biobased and biodegradable plastic, the following challenges exist in Malaysia:

- Transparency and a public campaign are needed to encounter the public confusion in differentiating between the biodegradability terms (e.g. biodegradable, compostable, and oxo-degradable).

- Currently, there are no means to prevent the import of oxo-degradable plastics into Malaysia due to a lack of a certification or declaration scheme for oxo-degradable plastics. In addition, plastic bag manufacturers are able to use oxo-degradable plastics because declaration obligations and standards on plastic bag production are missing.

- There is no proper mechanism for food waste collection from residential areas and other institutions. Currently, source separation of food/organic waste, i.e. separation at the location where they are generated, is not mandatory for households or other waste generators. Thus, biodegradable plastic bags for the sorting of wet and dry household waste cannot unfold their potential due to the absence of an industrial-scale organic waste treatment infrastructure network: UNEP (2017) states that "the country does not have any full-scale/commercial plants for treating food/organic waste."

No specific bioplastics roadmap has been introduced in Malaysia so far. However, points of action on biobased and biodegradable plastic are included in the Malaysian Roadmap Towards Zero Single-Use Plastics (MESTECC 2018):

- During Phase II in 2022
  - Widespread uptake of bio bag nationwide replacing plastic bags and sold as Stock Keeping Unit item.
  - 'No straw by default' practice continues and extended to non-fixed premises. Eco-labelled (ECO001-compliant) straw will be introduced including straws for packet drinks.
  - Expansion scope of biodegradable and compostable products: Food packaging; plastic film; cutleries; food container; cotton buds; polybags and plant pots; and slow release fertilizers.

- During Phase III (2026-2030)
  - Substantial increase in the volume of production of local biodegradable and compostable alternative products for local consumption.
  - Expansion scope of biodegradable and compostable products: Single-use medical devices (e.g. catheter); diapers & feminine hygiene product; and other single-use plastics that cannot enter the circular economy.
  - Rapid testing kit for eco-labelling criteria for biodegradable and compostable plastic and bioplastic packaging materials (ECO001) compliant products deployed.

On the one hand side, an increasing trend in the use of biobased and biodegradable plastic is observed in line with the governmental vision as set out in the Roadmap Towards Zero Single-Use Plastic. On the other hand, full ambient degradation of biodegradable plastic is not realistic. Moreover, end-of-life management practices in the country do not allow to benefit from biodegradable plastic. It should be noted that source-segregation and separate collection of municipal and commercial waste, i.e. organic waste, are an important precondition. Furthermore, Life Cycle Assessment (LCA) studies have clearly shown that biobased plastics do not offer environmental advantages over fossil-based plastics. Preferring the use of biobased plastics over fossil-based alternatives only leads to burden shifting between different environmental impact categories (see pre-study on material choices based on LCA, Prakash et al. 2021). In this sense, it is concluded that the trend of the market clearly contradicts the recommendations set out in chapter 6: Biobased and biodegradable plastic does not meet the expectations for being a solution to domestic waste problems associated with single-us applications. Rather, guidance is needed on when and how biobased and biodegradable plastics can support the Circular Economy, and where it is disadvantageous.

5.2 Thailand

Since the Thai National Innovation Agency had published the National Roadmap for the Development of Bioplastic Industry (National Innovation Agency 2008) in 2008, Thailand has highly increased plastic production capacities: For biobased and biodegradable as well as for conventional plastic, Thailand has the largest production capacities in the Southeast Asian Region: Approximately 95,000 tons of biobased and biodegradable plastic per year, and 33.3 million tons of conventional plastic per year in 2018 (World Bank Group 2021b).

In terms of biobased and biodegradable plastic, Thailand's plastic industry mainly produces PLA and PBS (see chapter 2.1). As in Malaysia, the share of biobased resin produced in Thailand that is used domestically is 10-20 %, the remaining share is exported. According to the Thai National Innovation Agency (2008) and still today (World Bank Group 2021b), Thailand has 'ambitions to become a major regional bioplastic hub in line with the expected growth in the global bioplastics industry'. The Thai Bioplastic Industry is widely supported, e.g. by the Thai Board of Investments (Thailand Board of Investment 2014; 2019)

With regards to the situation for standards for biobased and biodegradable plastic, the Thai Industrial Standards Institute (TISI) published standards for compostable plastic. However, Thailand lacks industrial composting plants for organic materials (except for one facility in Bangkok). Thus, biobased and biodegradable plastic are disposed of in landfill sites without any interventions for enhanced composting. This poses problems as typically, PLA and PBS need a minimum temperature of 60°C, moisture and organic substate for aerobic degradation. Due to the lack of industrial composting facilities in Thailand, the bioplastics consumed in the country do not biodegrade in the post-consumer stage. Given the absence of a declaration or standard, oxo-degradable plastics pose further problems, even though prohibited since the beginning of 2020 according to the World bank (2021b). The same report states that the government does not have any implementation plan relating to the oxo-degradable plastic ban.

This situation causes a comparable challenging situation as identified for Malaysia:

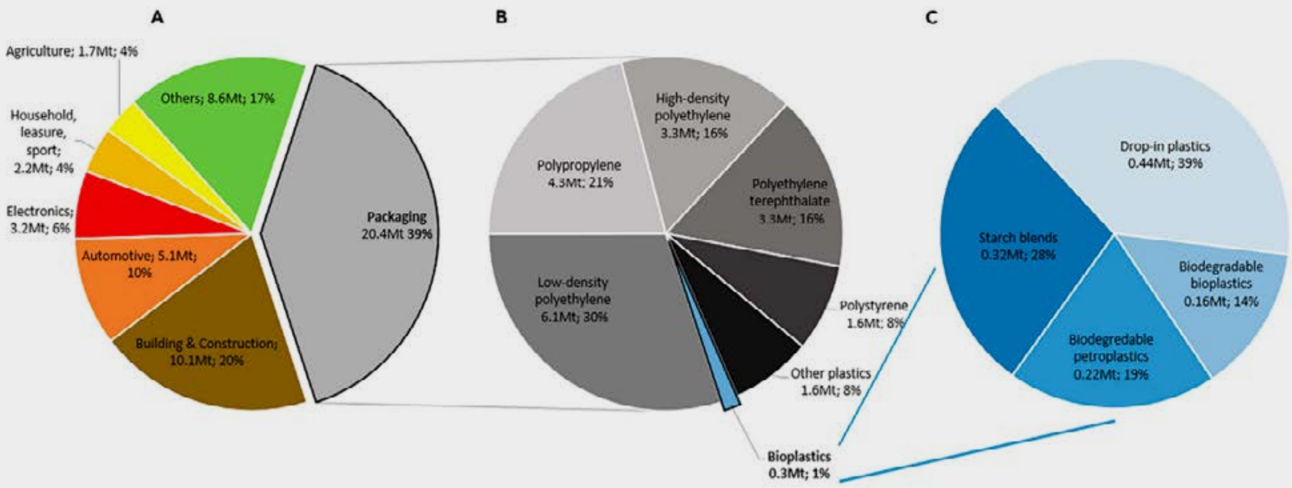
- Transparency and a public campaign are needed in order to counter the confusion existing on the part of the public in terms of differentiating between the biodegradability terms (e.g. biodegradable, compostable, and oxo-degradable).
- Currently, there are no means to prevent the use and import of oxo-degradable plastics due to the lack of any certification or declaration scheme for oxo-degradable plastics.
- According to UNEP (2017), 'difficulties in obtaining consistent source segregated organic waste are experienced. There is a need for a cost-effective technology for biomass utilization. Treatment technologies like composting [...] need to be replicated to reduce the MSW volume.'
- Biodegradable plastic bags for the sorting of wet and dry household waste cannot unfold their potential due to the lack of industrial composting plants for organic materials (except for one facility in Bangkok).

As for Malaysia but even at a faster pace, biobased and biodegradable plastic plays an important role for plastic items and packaging in Thailand. So far, guidance is lacking on when and how biobased and biodegradable plastics can support the Circular Economy, and where it is disadvantageous. For instance, an appropriate end-of-life treatment of biodegradable this kind of plastic is not ensured in Thailand. As also mentioned in the chapter on Malaysia, LCA studies have clearly shown that biobased plastics do not offer environmental advantages over fossil-based plastics. Preferring the use of biobased plastics over fossil-based alternatives only leads to burden shifting between different environmental impact categories (see GIZ and Oeko-Institut e.V. 2021b). It is concluded that the trend of the market clearly contradicts the recommendations set out in chapter 6. In this respect, expected advantages in terms of waste volume reduction and environmental benefits will not be realized as long as necessary supportive policies, e.g. mandatory labelling, standards and waste management practices (separate collection, sorting and organic waste treatment facilities) are not in place.

5.3 European Union

Biobased and biodegradable plastic represent 1 % (0.3 million tons) of 20.4 million tons of plastic packaging consumed in the European Union (see Figure 5-1). The production of biobased plastics amounted to 2.43 million tons of the global plastics production in 2019. Asia accounted for the largest share of biobased plastics production (45 %), followed by Europe at 25 %.

Figure 5-1: Volume and Share of Plastic Polymers Use in the European Union



Source: Figures from PlasticsEurope and European Bioplastics cited in Brizga et al. (2020)

Of the four types of plastics presented through the blue pie chart (in the figure above), drop-in plastics (39 %) are mainly non-biodegradable. For starch blends (28 %), biodegradability is unclear as it depends on the substances combined with starch to form the blend. For one third (19 % fossil-based plus 14 % biobased plastics), (industrial) biodegradability has been confirmed.

In the following, the legal situation for biobased and biodegradable plastic in Europe is summarized.

Generally, the EU Waste Framework Directive (WFD; Directive 2008/98/EC 2008, updated 2015 and 2018) with the waste hierarchy being its central instrument (Art. 4), is a piece of legislation covering overarching waste-related aspects. Thus, the 5 steps of the waste hierarchy also apply to waste biobased and biodegradable plastic: Prevention in the first place, followed by reuse under specific conditions, material recycling (currently rarely applied for biobased and biodegradable plastic), industrial and home composting, energy recovery through (co-)incineration and landfilling[15]. Additional provisions apply to biodegradable packaging mainly regulated through the Packaging and Packaging Waste Directive (PPWD; Directive 94/62/EC 1994, updated in 2018, review planned). Specifically, …

… Article 8a covers standardised labelling for biodegradable and compostable plastic carrier bags

… Annex II on the composition […] of packaging requires
  - 'That it [biodegradable packaging] should not hinder the separate collection and the composting process or activity into which it is introduced.'
  - That 'biodegradable packaging waste shall be of such a nature that it is capable of undergoing physical, chemical, thermal or biological degradation such that most of the finished compost ultimately degrades into carbon dioxide, biomass and water.'

15 According to the German Federal Ministry of Environment (2019), in Germany, less than 1 % of the plastic packaging waste is landfilled. It is assumed that this is also true for biobased and biodegradable plastic packaging.

The Single-Use Plastic Directive (SUPD; Directive (EU) 2019/904 2019) focusses on the reduction of the impact of certain plastic products on the environment. All provisions apply to single-use plastic of which biobased and biodegradable plastic are not excluded nor distinguished as a subgroup with specific provisions: "Plastics manufactured with modified natural polymers, or plastics manufactured from biobased, fossil or synthetic starting substances are not naturally occurring and should therefore be addressed by this Directive. The adapted definition of plastics should therefore cover polymer-based rubber items and biobased and biodegradable plastic regardless of whether they are derived from biomass or are intended to biodegrade over time." (Directive (EU) 2019/904 2019)

Although no EU-wide law addressing biobased, biodegradable and compostable plastics in a comprehensive manner has yet been implemented, individual EU Member States already have such policy in place mainly in relation to biowaste bags (60 % of regulated biodegradable products; see Table 5.2).

With the adoption of the EU Plastics Strategy (European Commission 2018a) and the Circular Economy Action Plan (European Commission 2020), the European Commission announced a dedicated policy framework on the sourcing, labelling and use of biobased plastics, and the use of biodegradable and compostable plastics. The proposal is expected to be published in the course of 2021. According to the European Environmental Agency (2020), such legal framework should include harmonised rules for defining and labelling compostable and biodegradable plastic. Furthermore, it shall serve as a basis for determining in which applications the use of such plastics has environmental benefits. Such benefits are expected for bio-waste collection bags, items attached to bio-waste, e.g. stickers on vegetables, tea bag labels, etc. or agricultural mulch films.

Table 5.2: Legal requirements on biodegradable plastic products in different EU Member States

Country	Legal requirements on biodegradable plastic products
Italy	Biodegradable plastic bags in accordance with EN 13432 and a minimum content of renewable raw material are exempt from the reduction requirements of plastic bags of ultra-light material.
France	Biodegradable plastic bags in accordance with EN 13432 are exempt from the plastic bag ban introduced in 2016.
Cyprus	Biodegradable waste bags are given priority under public procurement specifications resulting in indirect financial incentives.
Germany	Plastic bags certified according to EN 13432 may be used for collecting bio-waste except for regional waste specifications. Films used in agriculture made of biodegradable plastics, according to EN 13432, are allowed as input streams in composting plants.
Austria	Lower EPR-fees for biodegradable packaging material put on the market tha:n for material made of conventional plastics

Source: EPA Network 2018

Though only covering biodegradability of plastics, a scientific advisory group to EU institutions[16] (SAPEA 2020) suggests that the new legislation should contain the following recommendations:

- Adopt a joint **definition** of biodegradability;
- **Limit the use** of biodegradable plastics outdoors to specific applications for which reduction, reuse, and recycling are not feasible.
- **Do not consider** biodegradable plastics as a solution for inappropriate waste management or littering;
- Support the development of **coherent testing and certification** for biodegradability; and
- Promote the supply of **accurate information** on the properties, appropriate use and disposal, as well as on limitations of biodegradable plastics to relevant user groups.

16 Science Advice for Policy by European Academics (SAPEA) is part of the European Commission's Scien-tific Advice Mechanism, SAPEA provides independent scientific advice to European Commissioners to support their decision-making.

6 Conclusion and key implementation aspects

It is concluded that a simple substitution of fossil-based materials by biobased alternatives is not appropriate to encounter problems associated with waste generation. Furthermore, this substitution does not lead to environmental benefits to the extent needed in the light of the challenges associated with plastic and packaging waste. Furthermore, biobased and biodegradable materials shall not undermine the waste hierarchy according to which the avoidance of waste is preferred over all other options.

Besides providing background information, this paper aims to explain the various risks and objecttions associated with biobased and biodegradable plastic. Authors of this study conclude in accordance with the German Federal Environment Agency (UBA) (2017) …

… with regards to biobased plastic, that …

- … substituting conventional through biobased plastic brings no real environmental benefit but will rather shift the environmental burden: While biobased plastics have a lower impact on the global warming potential, they are responsible for higher acidification and more intense land use. The latter entails problems such as increased fertiliser and pesticides use, land use conflicts in the context of food production. Thus, it likely to entail greater impacts on biodiversity losses and soil degradation.

- … not all biobased materials are 100 % biobased, the reason being that certification and labelling of the biobased content in plastics is possible for 20 %, 50 % or 85 % of the natural raw material used. This differentiation bears the risk of confusing consumers even more than the whole issue has hitherto done.

- … certification of origin and sustainable cultivation of biomass should be considered in addition to the share of biomass used in a product.

- … with regards to biodegradable plastic that …

- … in general, for both biodegradable as well as conventional plastics, physical, chemical and biological effects lead to the fragmentation of plastics in the environment. Even if the material degrades to an extent of at least 90 % in the end, in the meantime, micro particles as well as hazardous substances associated with the plastic fragments may leach or entail adverse effects.

- … the current waste management infrastructure is not adapted to the high-quality recovery of biodegradable plastics, neither in Europe (see chapter 5.3) nor in South-East Asia (see chapters 5.1 and 5.2). It is questionable whether investments in such infrastructure are justified against the background that biologically degradable plastics have only limited value for recycling anyway.

- … tackling high waste volumes through biodegradable plastics that are disposed of in organic waste management is not in line with the waste hierarchy. Rather, reduction, reuse and recyclable packaging should be preferred.

The assessment of biobased and biodegradable plastic materials is not straightforward. Before taking decisions on the selection of the material for plastics, it is important to consider their environmental impacts, possible trade-offs and specific end-of-life options in the local context. Figure 6-1 provides an overview of the most important action points with regards to biobased and biodegradable plastic. These points do not require further assessment but could be taken over as short-term recommendations.

Figure 6-1: Five To-Do's about biobased and biodegradable plastic

Source: Own compilation supplemented with recommendations from EPA Network 2018

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Annex

Table A-1: Biological degradation of biodegradable plastic in different environments

(a) Biological degradation of biodegradable plastic under industrial composting conditions (50-60 °C)

Material	Temperature	Degradation Degree	Time	Source
TPS	58 °C	80 %	45 days	Shin et al. 2004
PLA bottle	58 °C	84 %	58 days	Kale et al 2007b
PHA	55 °C	~80 %	28 days	Tabasi und Ajji 2015
PBS/starch blend (film)	58 °C	100 %	45 days	Jayasekara et al 2003
PCL (500 µm film)	58 °C	40 %	45 days	Shin et al. 2004

(b) Biological degradation of biodegradable plastic in soil

Material	Temperature	Degradation Degree	Time	Source
PLA (Powder, 500 µm)	20 °C	< 1 %	186 days	Fraunhofer Umsicht
PHA (film, 620 µm)	20 °C	~70 %	660 days	Gomez & Michel 2013
PBS/TPS (powder)	25 °C	25 %	28 days	Adhikari et al. 2016
PCL	20-25 °C	~20 %	125 days	Solaro et al. 1998

(c) Biological degradation of biodegradable plastic in aqueous milieu

Material	Temperature	Degradation Degree	Time	Source
PLA (Powder, 500 µm)	20 °C	< 10 %	118 days	Fraunhofer Umsicht
TPS/Cellulose	20-25 °C	~80 %	55 days	Catia Bastiolli 1998
PCL (Powder 500µm)	20 °C	> 90 %	28 days	Fraunhofer Umsicht

Note: The figures are individual measurements that strongly depend on the conditions during the degradation experiment, e.g. the type of soil, pH of aqueous milieu, etc. The figures provide an indication, but different numbers can be found in case of changes of the methodological setup.

Source: Based on a compilation provided by the authors of Umweltbundesamt 2018

Table A-2: Main ISO and CEN standards relating to biodegradability of plastics

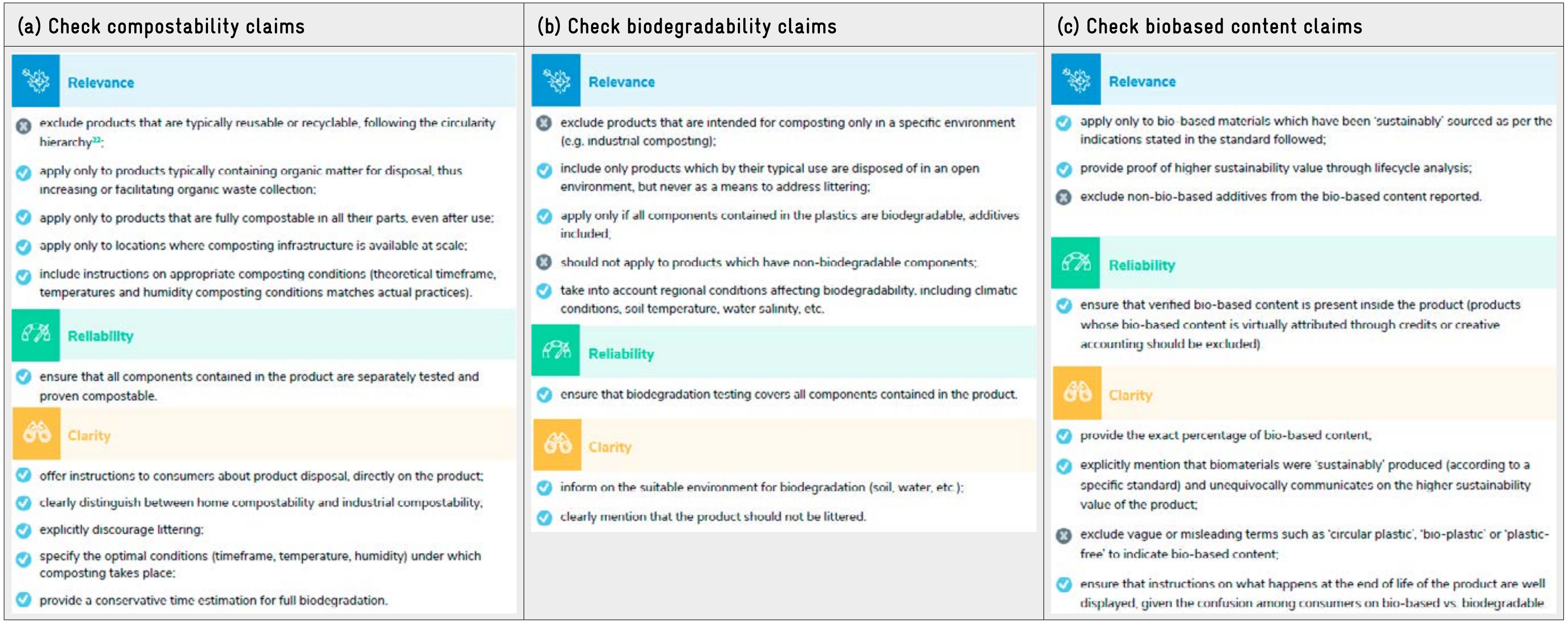
Standard Title
EN ISO 10210:2017 Plastics – Methods for the preparation of samples for biodegradation testing of plastic materials (ISO 10210:2012)
EN 14995:2006 Plastics – Evaluation of compostability – Test scheme and specifications
EN 13432:2000 Packaging – Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging
EN 14046:2003 Packaging – Evaluation of the ultimate aerobic biodegradability of packaging materials under controlled composting conditions – Method by analysis of released carbon dioxide
EN 17033:2018 Plastics – Biodegradable mulch films for use in agriculture and horticulture–Requirements and test methods
ISO 17088:2012 Specifications for compostable plastics
EN ISO 14855-1:2012 / EN ISO 14855-2:2018 Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions – Method by analysis of evolved carbon dioxide – Part 1: General method (ISO 14855-1:2012) – Part 2: Gravimetric measurement of carbon dioxide evolved in a laboratory-scale test (ISO 14855-2:2018)
EN ISO 16929:2019 Plastics – Determination of the degree of disintegration of plastic materials under defined composting conditions in a pilot-scale test (ISO 16929:2019)
EN ISO 20200:2015 Plastics – Determination of the degree of disintegration of plastic materials under simulated composting conditions in a laboratory-scale test (ISO 20200:2015)
ISO 23977-1:2020 / ISO 23977-2:2020 Plastics–Determination of the aerobic biodegradation of plastic materials exposed to seawater – Part 1: Method by analysis of evolved carbon dioxide – Part 2: Method by measuring the oxygen demand in closed respirometer
EN ISO 14853:2017 Plastics – Determination of the ultimate anaerobic biodegradation of plastic materials in an aqueous system – Method by measurement of biogas production (ISO 14853:2016)
EN ISO 14851:2019 Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium – Method by measuring the oxygen demand in a closed respirometer (ISO 14851:2019)
EN ISO 14852:2018 Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium – Method by analysis of evolved carbon dioxide (ISO 14852:2018)
EN 17417:2020 Determination of the ultimate biodegradation of plastics materials in an aqueous system under anoxic (denitrifying) conditions – Method by measurement of pressure increase

Standard Title
EN ISO 10634:2018 Water quality – Preparation and treatment of poorly water-soluble organic compounds for the subsequent evaluation of their biodegradability in an aqueous medium (ISO 10634:2018)
EN ISO 14593:2005 Water quality – Evaluation of ultimate aerobic biodegradability of organic compounds in aqueous medium – Method by analysis of inorganic carbon in sealed vessels (CO2 headspace test) (ISO 14593:1999)
EN ISO 11733:2004 Water quality – Determination of the elimination and biodegradability of organic compounds in an aqueous medium – Activated sludge simulation test (ISO 11733:2004)
EN ISO 17556:2019 Plastics – Determination of the ultimate aerobic biodegradability of plastic materials in soil by measuring the oxygen demand in a respirometer or the amount of carbon dioxide evolved (ISO 17556:2019)
EN ISO 11266:2020 Soil quality – Guidance on laboratory testing for biodegradation of organic chemicals in soil under aerobic conditions (ISO 11266:1994)
EN ISO 15985:2017 Plastics – Determination of the ultimate anaerobic biodegradation under high-solids anaerobic-digestion conditions – Method by analysis of released biogas (ISO 15985:2014)
EN ISO 18830:2017 Plastics – Determination of aerobic biodegradation of non-floating plastic materials in a seawater/sandy sediment interface – Method by measuring the oxygen demand in closed respirometer (ISO 18830:2016)
EN ISO 19679:2020 Plastics – Determination of aerobic biodegradation of non-floating plastic materials in a seawater/sediment interface – Method by analysis of evolved carbon dioxide (ISO 19679:2020)
ISO 13975:2019 Plastics – Determination of the ultimate anaerobic biodegradation of plastic materials in controlled slurry digestion systems – Method by measurement of biogas production
ISO 22404:2019 Plastics – Determination of the aerobic biodegradation of non-floating materials exposed to marine sediment – Method by analysis of evolved carbon dioxide
ISO/DIS 23517-1 (under development) Plastics – Biodegradable mulch films for use in agriculture and horticulture Part 1: Requirements and test methods regarding biodegradation, ecotoxicity and control of constituents

Source: Table 3 in Di Bartolo et al. 2021

Additional information on standards is available from Table 4 (List of CEN and ISO standards, technical reports and specifications, relevant to the life cycle assessment of bioplastics) in Di Bartolo et al. (2021).

Figure A-2: ECOS Claim Checklist for assessment of Green Claims on Products for relevant product categories



(a) Check compostability claims

Relevance

- ✗ exclude products that are typically reusable or recyclable, following the circularity hierarchy[32];
- ✓ apply only to products typically containing organic matter for disposal, thus increasing or facilitating organic waste collection;
- ✓ apply only to products that are fully compostable in all their parts, even after use;
- ✓ apply only to locations where composting infrastructure is available at scale;
- ✓ include instructions on appropriate composting conditions (theoretical timeframe, temperatures and humidity composting conditions matches actual practices).

Reliability

- ✓ ensure that all components contained in the product are separately tested and proven compostable.

Clarity

- ✓ offer instructions to consumers about product disposal, directly on the product;
- ✓ clearly distinguish between home compostability and industrial compostability;
- ✓ explicitly discourage littering;
- ✓ specify the optimal conditions (timeframe, temperature, humidity) under which composting takes place;
- ✓ provide a conservative time estimation for full biodegradation.

(b) Check biodegradability claims

Relevance

- ✗ exclude products that are intended for composting only in a specific environment (e.g. industrial composting);
- ✓ include only products which by their typical use are disposed of in an open environment, but never as a means to address littering;
- ✓ apply only if all components contained in the plastics are biodegradable, additives included;
- ✗ should not apply to products which have non-biodegradable components;
- ✓ take into account regional conditions affecting biodegradability, including climatic conditions, soil temperature, water salinity, etc.

Reliability

- ✓ ensure that biodegradation testing covers all components contained in the product.

Clarity

- ✓ inform on the suitable environment for biodegradation (soil, water, etc.);
- ✓ clearly mention that the product should not be littered.

(c) Check biobased content claims

Relevance

- ✓ apply only to bio-based materials which have been 'sustainably' sourced as per the indications stated in the standard followed;
- ✓ provide proof of higher sustainability value through lifecycle analysis;
- ✗ exclude non-bio-based additives from the bio-based content reported.

Reliability

- ✓ ensure that verified bio-based content is present inside the product (products whose bio-based content is virtually attributed through credits or creative accounting should be excluded)

Clarity

- ✓ provide the exact percentage of bio-based content;
- ✓ explicitly mention that biomaterials were 'sustainably' produced (according to a specific standard) and unequivocally communicates on the higher sustainability value of the product;
- ✗ exclude vague or misleading terms such as 'circular plastic', 'bio-plastic' or 'plastic-free' to indicate bio-based content;
- ✓ ensure that instructions on what happens at the end of life of the product are well displayed, given the confusion among consumers on bio-based vs. biodegradable

Source: (ECOS; Rethink Plastic; #breakfreefromplastic 2021)

Too good to be true? A study of green claims on plastic products ➦ https://ecostandard.org/wp-content/uploads/2021/07/ECOS-RPa-REPORT-Too-Good-To-Be-True.pdf

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