WHITE PAPER

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From afterthought to strategic positioning - a white paper on how a future bioplastic system could contribute to EU policies in the transition to a circular economy.

This document has been produced on behalf of, and in collaboration with, the BIO-PLASTICS EUROPE project.

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2 ABSTRACT

The BIO-PLASTICS EUROPE Consortium of 22 partners initiated its activities on the 1st of October 2019 and was operational for 52 months, ending on 31st January 2024. The strong focus of the project was on providing recommendations to the EU policy makers on bio-based and biodegradable plastics.

Within the project 2 policy briefs, projects2policy concept, sustainability framework, 2 networks, waste management handbook and social media filter and virtual engagement tool have been produced. The recommendations coming from the project BIO-PLASTICS EUROPE and the solutions already produced have been summarized in this white paper.

3 PROBLEM STATEMENT

This white paper suggests that bioplastics are often an afterthought within current EU policy and therefore not properly considered or accommodated within evolving policy developments. As such, the European Bioplastic system is not functioning as well as it could be and its contribution to the circular economy is not being fully realised.

4 BACKGROUND

4.1 Broader issues related to traditional plastics

Plastic has become ubiquitous in modern society due to the huge environmental implications regarding its production and disposal. Production is currently coupled with the use of fossil resources – implications for carbons emissions, resource depletion, geopolitical conflicts, issues related to litter and waste – impacts to species and ecosystems.

The EU has recognised the significance of the plastic problem with the introduction of several strategies (such as the EU Plastic Strategy, European Green Deal and Bioeconomy strategy) that attempt to address issues related to the production, consumption and end-of-life management of plastics from different points of view. These strategies are supported by a range of policies that target specific elements of the plastic problem, including the following:

- **Single Use Plastic Directive** – aims to reduce the volume and impact of certain (single-use) plastic products on the environment.
- **Plastic Bag Directive** – adopted to deal with the unsustainable consumption and use of lightweight plastic carrier bags.
- **Plastic Packaging and Packaging Waste Directive** – Seeks to deal with the increasing quantities of packaging waste, which cause environmental problems and to remove barriers by aligning rules on packaging design.
- **Waste Framework Directive** - Sets the basic concepts, definitions and targets related to waste management.

4.2 Focus on bio-based and biodegradable plastics

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While the European Commission aims to avoid the usage of the term 'bioplastics', it is often used in reference to a family of materials, as illustrated by Figure 1. In general, there are three major categories of bioplastics (Leal Filho et al., 2021):

• Plastics that are derived from renewable resources (also referred to as bio-based, bio-sourced, or bio-derived) which exhibit biodegradable characteristics.

• Plastics that are made using fossil fuels (oil) but also exhibit biodegradable characteristic.

• Plastics that are derived (or partly derived) from renewable resources but do not exhibit biodegradable characteristics. These materials have the same chemical structure as the conventional plastic they are substituting and are often referred to as "drop-in" plastics.

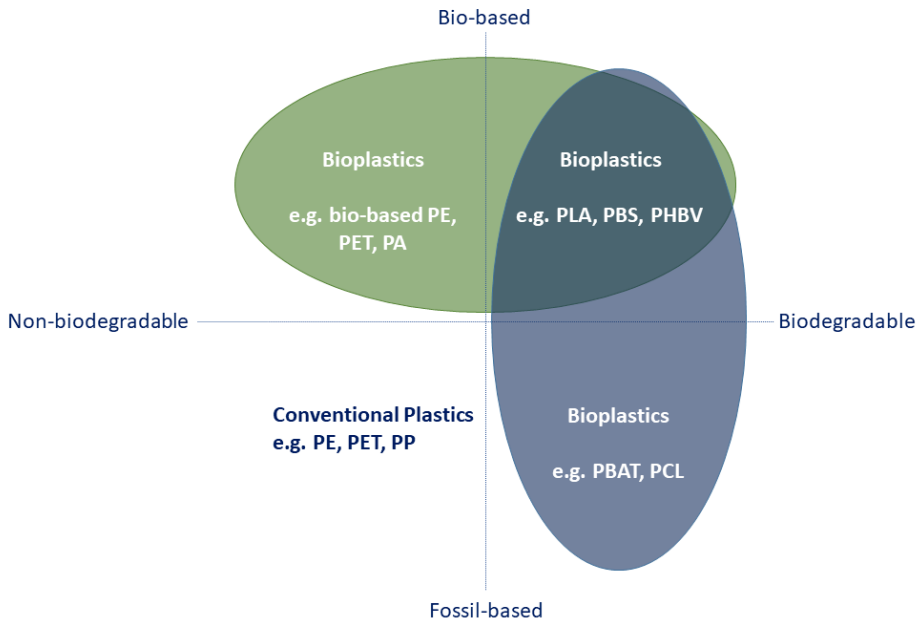

Figure 1: What are bioplastics? Source: European Bioplastics e.V.

Bioplastics currently only represents <1% of the 390 million tonnes of plastics produced annually. Using complied market data, European Bioplastics (industry association), in association with the Nova-Institute (research organisation), have estimated that global bioplastic production capacity will increase from circa. 2.2million tonnes in 2022 to approximately 6.3 million tonnes in 2027 (EUBP, 2022) Other predictions indicate that bioplastics could make up to 40% of the plastics market by 2030 (Statista, 2023). However, the biggest disadvantage of bioplastic, and thereby a significant barrier to increased market share, continues to be the high production cost (Slezak et al., 2023).

In line with the scope of the BIO-PLASTIC EUROPE project, the remainder of this white paper will focus on bio-based and biodegradable plastics.

Bio-based plastics substitute the use of fossil fuels in the production of plastics by utilising biomass, a resource that has the advantage of regenerating annually. The type of resource used is referred to as its "feedstock". The feedstocks that contemporary biobased plastics use

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can be divided into different generations (first, second and third) according to their development stage. While it is relatively straightforward to assign first generation feedstocks, there is no generally accepted definition of the second and third generation in the literature (Wellenreuther, Wolf, & Zander, 2022). The BIO-PLASTICS EUROPE project has adopted the following definitions.

- **First-generation** feedstocks are usually carbohydrate-rich plants that are also suitable as food or animal feed. Today, most bioplastics products using first-generation feedstocks such as corn and sugar cane.
- The **second generation** includes feedstocks that are not suitable for food or animal feed. These can be either non-food crops (e.g., cellulose) or by-products from first-generation feedstocks such as corn stover or sugarcane bagasse. The use of second-generation feedstocks has not yet reached a high degree of commercialization.
- The **third generation** includes the currently most innovative feedstocks, which are still at an early stage of development. They include biomass from algae, industrial or production wastes, and municipal (food) waste.

Biodegradability is an add-on property that can offer additional end-of-life options but cannot be confused with other terms as compostability and bio-based (Figure 2).

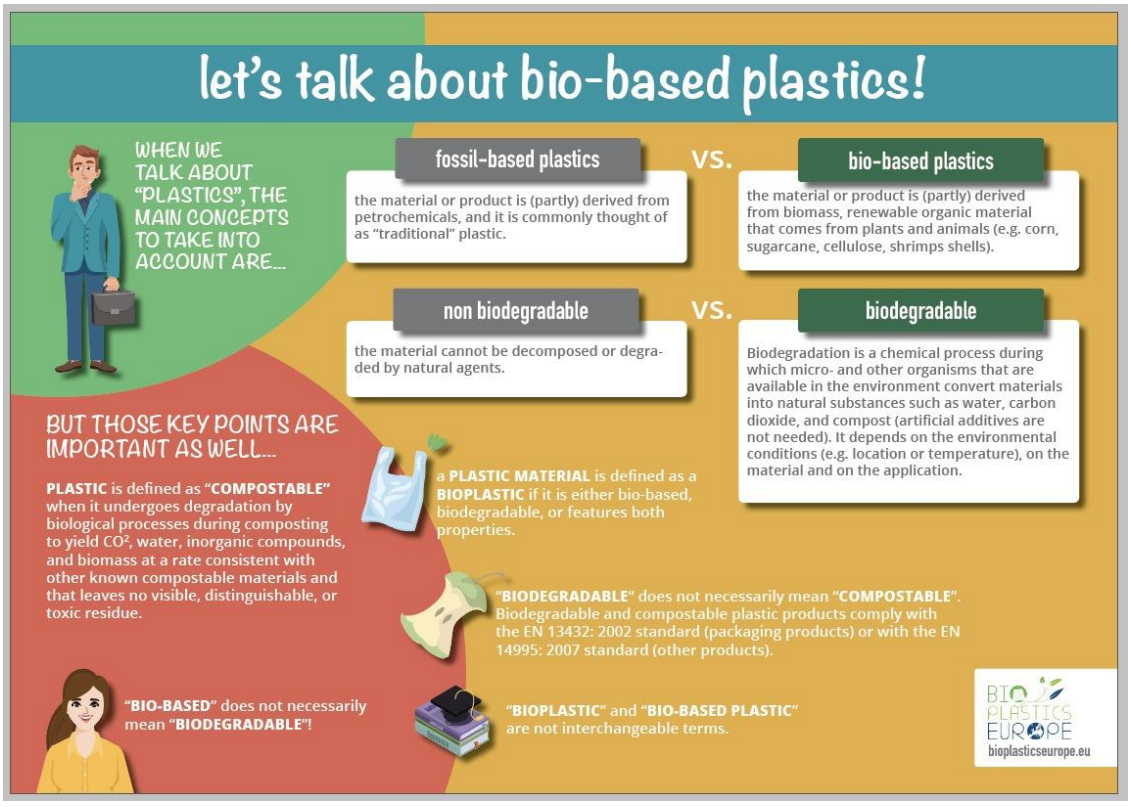

Figure 2: Clarification of the "bioplastics terminology"

"BIO-BASED" DOES NOT NECESSARILY MEAN "BIODEGRADABLE"!

Biodegradation is a microbial process, which in the presence of oxygen leads to the breakdown of organic constituents in a material which results in the production of carbon dioxide (CO_2), water, mineral salts, and new biomass. This process can also happen in the

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absence of oxygen, where CO_2, methane, mineral salts, and new biomass are produced (SAPEA, 2020). Biodegradation is a system property resulting from the dynamics between the specific properties of a material (that allow it to be potentially biodegradable) and the biotic (abundance of microorganisms) and abiotic (weather, moisture level, oxygen content, soil properties, etc.) conditions in which the material is found (Slezak et al., 2023).

Where the rate of biodegradation in specific environmental conditions can be shown to be consistent with known compostable materials (such as food waste) and no visible, distinguishable, or toxic residues are left after a pre-determined timeframe, the material can be described as compostable.

"BIODEGRADABLE" DOES NOT NECESSARILY MEAN "COMPOSTABLE".

Compostable plastic is always biodegradable, but not every plastic that is biodegradable is compostable. Compostable plastic products should comply with the EN 13432:2002 standard (packaging products) or the EN 14995:2007 standard (other products), where to meet the criteria it must; disintegrate and biodegrade over a specific timeframe, be a thickness sufficiently low enough to enable a full disintegration in a composting cycle, demonstrate concentration of metals below specific limits; and after biodegradation, it should not cause any toxic persistent effects.

4.2.1 Consumer acceptance of bio-based and biodegradable plastics

While efforts have been made by the EU to standardize the terminology used regarding bio-based, biodegradable, and compostable plastics, a disconnect between information providers and the consumer persists. As such, consumer confusion and the potential for "green washing" may limit the uptake of these alternative materials in the end-user market. Questions of the legitimacy of environmental credentials and technical performance has also been raised by the media (Fletcher et al., 2021). Through stakeholder engagement activities, Fletcher et al. (2021) explored the importance of clear and robust communication across the value chain as well as the role of lifecycle thinking, intra-national policy support and broader awareness/educational campaigns to encourage the market uptake of bio-based and biodegradable plastics where suitable.

When soliciting the opinions of the consumers through a survey, results suggest that potential barriers for the uptake of alternative plastics (particularly bio-based and biodegradable plastics) are caused by continued confusion, unrealistic expectations, and the value-action gap (Leal Filho et al., 2022). While these barriers are visible at the consumer level, they have wider implications across the entire value chain. To improve consumer acceptance, it is suggested that the role and success of interventions such as education, choice editing and mechanisms to improve the clarity and accessibility of information should be explored (*ibid*.).

Another survey conducted to evaluate the perceptions of Europeans on the use of plastics and bioplastics gathered evidence which suggested that participants (categorized as highly educated with 92% having achieved a bachelor's degree, master's degree, or PhD) report an awareness about the problems associated with plastic use and are interested in reducing the use of plastics by adopting sustainable alternatives (Leal Filho et al., 2021). This confirms the

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role that education and awareness can have for the promotion of plastic alternatives such as bio-based materials. Conclusions of the Leal Filho et al. (2021) survey on how to promote the uptake of bio-based and biodegradable plastics are illustrated in Figure .

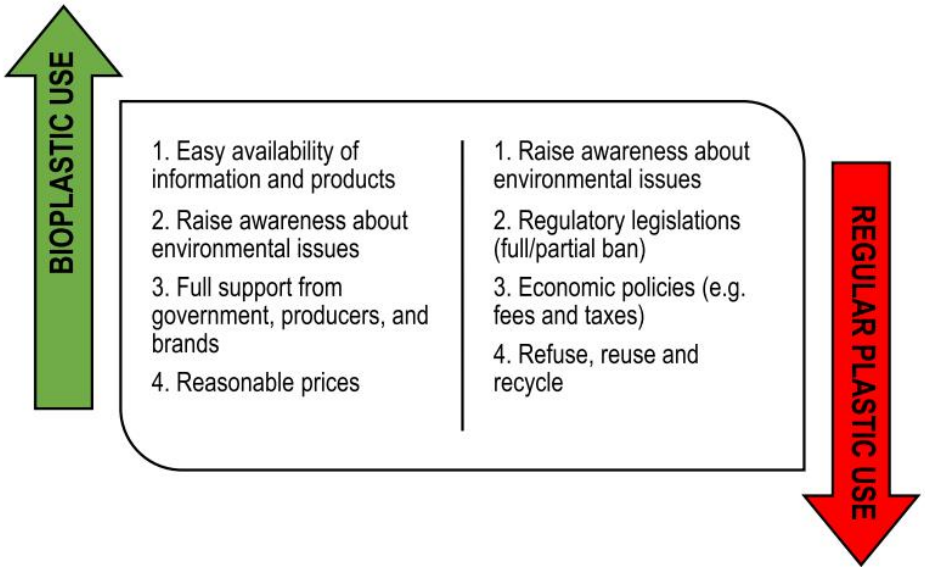

Figure 3: Mechanisms to promote the uptake of bio-based and biodegradable plastics, and to abate conventional plastic use (taken from Filho et al., 2020)

4.2.2 Sectors and applications

While bio-based plastic alternatives exist for almost every conventional plastic material and application, this white paper (in line with the scope of the BIO-PLASTICS EUROPE project) will focus on the following product groups; toys, packaging (rigid and soft), cutlery, agricultural mulch films, and multiple fisheries products (baits/lures, crates and geomembranes).

The following sub-sections will introduce each product group in turn, highlighting details regarding intended use profile, suitability for biodegradation and end-of-life scenarios. It will also reflect on specific policy instruments that are targeted at the different products groups.

4.2.2.1 Toys

The first product group being considered are Toys, with a specific focus on beach/sand toys. Sand toys are made from rigid plastic, generally acrylonitrile butadiene styrene (ABS) or polypropylene (PP) that is made to be durable during use. They are produced for use by children aged 3+ years old, under adult supervision.

Safety: All toys, regardless of type, need to adhere to Directive 2009/48/EC on the Safety of Toys. This directive, as well as a comparable US policy (the US Consumer Product Safety Improvement Act of 2008) were developed after a series of violations of existing safety standards saw more than 19 million toys recalled worldwide in one year.

The Toy Safety Directive (2009/48/EC) lays down provisions concerning assessment of conformity, CE marking and market surveillance for product entering the community market. It also provides obligations for manufacturers, importers, and distributors. Before placing a toy on the market, analysis of any chemical, physical, mechanical, electrical, flammability,

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hygiene and radioactivity hazards that the toy may present, as well as an assessment of the potential exposure to such hazards, should be completed.

A key component of Directive 2009/48/EC is the use of the EC-label to highlight conformity and the use of appropriate warnings. Requirements of the EC-label states that any warning should be clearly visible, easily legible and understandable, and accurate, attached either on an affixed label, on the toy itself or accompanying instructions.

A further consequence of these policies was the emergence of a series of international safety standards, namely ISO 8124 series, ASTM F963 series and the EN-71 series.

Biodegradability: Added value is unclear - The rational of using bio-based, biodegradable and compostable plastic for *reusable beach toys* is to reduce the environmental impact in case of littering. Beach toys plastic needs to be able to degrade in all environments as the material is intended to be used in, and can thus be lost in, different types of environments.

4.2.2.2 Packaging (rigid and soft)

The second product group being considered is packaging, with a specific focus on rigid cosmetics packaging as well as rigid and soft food packaging. Rigid food packaging, such as that used for cosmetic and drinks bottles, is generally made from high density polyethylene (HDPE), polypropylene (PP) and polystyrene (PS). Soft food packaging, such as that used for yoghurt pots are generally made from polyethylene (PE) and polypropylene (PP). The primary function of any type of packaging is to contain and protect the contents by providing a barrier to water, oxygen, leakage, contamination, etc.

Safety (food contact): Food contact materials are ubiquitous in everyday life. When in contact with food, these materials may behave differently and transfer their constituents to the food. Some constituents, if in large enough quantities, may create a risk to human health or change the food itself, therefore these materials are subject to legally binding rules and regulations.

Any material that comes into contact with food must adhere with food safety laws, namely the Regulations (EC) 1935/2004 and (EC) 2023/2006, which are applied to all materials, and Regulation (EU) 10/2011 that is focused on plastic materials and provides a revision known as the Plastic Implementation Measure (PIM).

In line with EU General Food Safety Law, Regulation (EC) 1935/2004 focuses on food contact materials. Key objectives of this directive are to ensure the effective functioning of the internal market and to secure a high level of human health and consumer protection. To do this, (EC) 1935/2004 sets out two main requirements; (1) all food contact material should be manufactured using 'Good Manufacturing Practices' (as defined by (EC) 2023/2006) so that under normal conditions and usage, they do not transfer their constituents to food in quantities that could endanger human health, bring about unacceptable changes in composition or causes deterioration of organoleptic characteristics (flavour, colour, texture, etc.), and, (2) any labelling, advertisement or presentation of the material should not mislead the consumer (EC, 2004). Suitability for food contact can be indicated through the words 'for food contact', reference to a specific use (e.g., wine bottle, soup spoon etc.) or by using the food grade symbol.

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Where the food contact material contains plastic (either exclusively or as part of a multi-layer material), regulation (EU) 10/2011 should also be adhered to. This regulation applies to plastic materials and products intended to come into contact with food, already in contact with food or can reasonably be expected to come into contact with food. This regulation sets out specific and overall migration limits such that the plastic material or product should not transfer constituents to foods in quantities that are harmful to human health.

Biodegradability: Added value is dependant - For *Rigid packaging for cosmetics* the added value of using biodegradable or compostable rigid packaging is not clear. This is due to the fact that the application does not contain food residue/organic residue, therefore mechanical or chemical recycling may be considered more suitable. However, for *soft packaging for food,* the added value of using biodegradable (specifically compostable) plastic is dependent on the food type being contained. For example, in cases where the food stuff being contained leaves an organic residue (i.e., liquid and semi-liquid products such as beverages, sauces, condiments, preserves, marinated items, etc.), then the added value of using biodegradable and compostable plastic is apparent, as it would allow the consumers to discard the packaging into the organic waste fraction destined for organic recycling. For food applications where organic residues are not present after use, the same rationale does not always apply. These packages may be more suitable to be made from bio-based plastic that may be recycled, either mechanically or chemically, as the material may be treated together with conventional plastic in infrastructure that is more widely available in some European countries.

4.2.2.3 Cutlery

The third product group being considered is reusable outdoor cutlery. Reusable outdoor cutlery is generally made from polypropylene (PP), with rigid, durable characteristics, that allow for stability during use and heat-proof properties, for example when in contact with hot foods and/or dish-washer cycles.

Safety: As with the packaging products highlighted above, reusable outdoor cutlery has to adhere with the rules and requirements concerning the Food Contact Materials regulations and the General Product Safety Directive. As well as ensuring that the materials used, and the design of these products, adhere with Food Contact Material regulations and General Product Safety, it has been recommended that reusable plastic cutlery show heat-proof properties, specifically resistance to mechanical dish washing. Testing the resistance of domestic articles, such as plastic cutlery, to mechanical dish washing, EN 12875-1:2015 provides a test method that incorporates the combined chemical, thermal and mechanical stresses expected in the use of domestic dishwashers.

Biodegradability: Added value is unclear - The rational of using bio-based, biodegradable and compostable plastic for *reusable cutlery* is to reduce resource consumption and the environmental impact in case of littering. The added value of using a biodegradable plastic for cutlery is not clear, due to various aspects that speaks against its use. Some examples are that the product can be recycled in current recycling infrastructure and that biodegradable plastic only degrades in appropriate conditions and sufficient time. However, biodegradability is most suitable in cutlery for multi-use / closed-loop scenario (e.g., event catering), where compostable cutlery can be collected together with food waste for organic recycling.

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4.2.2.4 Agricultural Mulch films

The fourth product group being considered are agriculture products, specifically mulch films. Mulch films are generally made from polyethylene (PE). The purpose of mulch films is to provide protection and/or to add fertilizer or fungicide to agricultural fields. They can be designed to be used and removed, where they are then disposed of or recycled. Others are designed to be left on the soil, where they biodegrade in a controlled fashion after a fixed period of time.

Safety: CEN have developed several technical standards concerning the use of agricultural films. These standards cover silage bale wrapping, barrier (fungicide) films, recyclable silage/mulching films and other thermoplastic covering films. For the purpose of this report, only standard EN 17033:2018 has been evaluated to be within the scope of the overall Bio-plastics Europe project. The overall objective of this standard is to ensure that the film will biodegrade in soil without creating any adverse environmental impacts. It specifies test methods to determine the control of constituents, biodegradation, ecotoxicity, appearance and technical properties. It also provides the requirements for the packaging, identification and marking of films. This standard defines a classification of biodegradable mulch films according to their service life on soil and provides a good practice guide for the use of such films.

Biodegradability: Added value is clear - During the use phase, utilising biodegradable mulch film may reduce associated labour and resource costs as it can be left on the field to biodegrade (does not require the labour/time cost of removal). However, to maximise the proficiency of this system, the material must be fully biodegradable and non-toxic in all ecosystems. To ensure these characteristics, the biodegradability of the material needs to be tested and approved under local conditions, in addition to any functionality requirements.

4.2.2.5 Fisheries products (fishing baits, crates and geomembranes)

The final product group that is being considered are fisheries and aquaculture products; namely fishing bait (also known as lures), fish transport crates and marine geomaterials.

Plastic fishing bait, or lures, are mainly used in recreational angling and closely resemble, and therefore provide an alternative to live bait. While there are hundreds of different types and brands of fishing lures, generally they are made from softened plastic such as polyvinyl chloride (PVC). Their durability and subsequent longevity, as a result of being composed of inert non-biodegradable synthetic polymers, means that they can be reused and thus, multiple fish can be caught during a lure's lifetime.

Fish transport crates are generally made from high density polyethylene (HDPE). They are used to store fresh fish and to aid transportation between fishing vessel and appropriate marketplace (i.e., retail, wholesale, etc.). They are designed to be durable so that they are resistant to high impacts and can be reused multiple times.

Marine geomaterials are one of many geotechnical engineering materials, also known as geosynthetics or geotextiles, which are generally made from polyethylene (PE), polypropylene (PP), polyester, and polyvinyl chloride (PVC). They are utilised in a range of geotechnical engineering applications, where they are used to (1) prevent the migration of

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liquids (and/or gases), (2) contain soils and sediments, (3) drain, collect and transport liquids, (4) filter fluids from soils, (5) prevent or reduce localised stress, (6) reinforce structures, (7) prevent intermixing of two dissimilar materials, (8) control surface erosion and/or (9) increase or reduce frictions across an interface. The marine geomaterials specifically considered within the BIO-PLASTICS EUROPE project concern those used to contain and support embankments. While the geomaterials restrict the movement, and therefore loss, of soils and substrate, they also allow the growth of vegetation such as seagrass that in turn replace the binding structure given by the geomaterial.

Safety: The aquaculture products listed here must adhere with the General Product Safety (GPS) Directive to ensure that they are fit for purpose and are made of a suitable quality. Other issues, specific to the three product types, that may require further consideration are noted below.

Fishing bait / lures: A key issue regarding the use of plastic lures reflect the consequences of when a lure is lost, i.e., either ingested by the fish (immediately or through foraging) or lost to the environment. If a lure was to be ingested, it may act as a 'bezoar' (a non-digestible, non-degradable foreign object that obstructs the gastrointestinal tract) particularly if the lure contains porous plastic that swells when water is absorbed. The subsequent consequence of this may be a reduction in body condition and possibly anorexic behaviour. For those lost in the environment, due to their durability they do not degrade and thus remain in the environment for a prolonged time. Whilst settled on the bottom, this increases the risk of being digested by fish, especially those who forage on the bottom. While this highlights potential fish-welfare issues, it also raises another: what is the impact of ingested plastic lures on the food chain, especially when considering species included within the human diet? Specifically concerning the bioaccumulation of plastics across species and the migration of harmful/toxic substances through the food chain.

Fish transport crates: Similar to food packaging, fish transport crates must be shown to adhere with Food Contact Materials regulations as they are used to store and transport food items. To determine which test conditions and methods are to be used to analyse overall migration of substances from materials and articles in contact with food, EN 1186-1:2002 should be consulted. Not only does this standard set out the types of tests that are applicable but also designates the most appropriate food stimulant. In light of the parameters laid down in this standard, the most suitable test methods in EN 1186-2 to EN 1186-9 would then be used. As this product is very likely to be used within very cold temperatures (e.g., freezers), the review of EN 1186-12 should also be taken into consideration.

Marine geomaterials: A key issue regarding the use of marine geomaterials is the environmental impact of degradation products and the emission of additives. As these geomaterials age, they become more brittle and therefore more likely to rupture and disaggregate. However, as this would also cause the material itself to fail, it can be seen as a technical issue. As such maintenance schedules that would identify early aging effects are important. So too, is the material selection, where the geomaterials used must be fit for purpose during the entire envisaged service life.

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Biodegradability: Added value is dependant - The rational of using biodegradable plastic for fishing baits is to reduce the environmental impact of lost fishing baits as the material degrades compared to conventional plastic. Compared to cutlery and beach toys, fishing baits is generally lost in aquatic environments and the risk of littering is higher as losses of baits occurs frequently and collection is not an option. In conclusion, an added value of using biodegradable plastic has been identified during the end-of-life phase. However, for fish crates the analysis concludes that a biodegradable option may not be the most suitable option. Several aspects speak against the use of biodegradable plastics for this application. Some examples are that the product can be recycled in current recycling infrastructure, the Reusable products that are meant to last would be more suitable to be produced in bio-based and/or conventional plastics to ensure that the material is durable. Additionally, the storage of fish in biodegradable plastic crates may affect the performance or functionality of the application during the use phase. For Aquatic geomembranes, the rational of using biodegradable geomembranes is that it can be left in the aquatic environment to degrade, which eliminates the need to remove the material after use, akin to the agricultural mulch films (i.e., reducing the associated costs, labour, and resources).

4.2.2.6 Product group summary

Table 1 summarises the information generated for each product groups within the BIO-PLASTICS EUROPE project, including details regarding [intended use profile, suitability assessment and end-of-life scenario].

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Table 1: Applications of focus within the BIO-PLASTICS EUROPE project.

Application	Intended use profile	Intended End-of-life scenario
Cutlery	Multiple use cutlery	Primary – recycling by producer themselves after long usage; secondary – industrial composting.
Toys	Durable products (e.g., beach toys) for use by children three years old and older.	Primary – recycling by producer; secondary: degradation in environment if lost.
Soft packaging	Food packaging such as yoghurt pot	Primary – industrial composting; secondary – mechanical recycling for post-industrial recycling.
Rigid packaging	Packaging suitable for cosmetics and food	Primary – post-industrial and post-consumer recycling; secondary – industrial composting.
Agricultural Mulch Films	Mulch film to cover fields during growth phase (agriculture application)	In-situ degradation.
Fishing Bait	Baits and lures for angling.	Primary – degradation in environment if lost; secondary – recycling by producer.
Fish Crates	Rigid or foamed crates to transport or store fish – multiple use	Primary – post-industrial and post-consumer recycling; secondary – industrial composting.
Marine Geomaterial	Thick film or sheets that stabilize ground before plants have grown sufficiently	In-situ degradation.

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4.2.3 Sustainability

Are bio-based biodegradable plastics actually sustainable? It is a question that has been asked many times.

On the one hand, the use of bio-based resources (specifically those based on natural, renewable sources) to create plastics should reduce our reliance on fossil resources, thus addressing one of the greatest contributors to climate change through reduced carbon emissions. Plus, the added property of being biodegradable opens up new waste management strategies which may have an impact on pollution and littering.

On the other hand, the use of renewable resources has been argued to be in conflict with other land use needs such as food production. This argument is particularly strong with respect to first generation feedstocks that typically use or displace food crops (such as sugar). To address this issue, scientists have been exploring the use of other feedstocks such as using food production co-products (i.e., using the stems or other inedible parts of the food crop, that are generally disposed of). These are known as second generation feedstock. More recently, the exploration of more innovative feedstocks (known as third generation) has begun to investigate the use of food waste, carbon capture and algae, for example.

Within the BIO-PLASTICS EUROPE project, the concept of sustainability has been considered from several perspectives. For this reason, within the project **Sustainability Framework for bio-based plastics** has been developed and is available on the project's website (https://bioplasticseurope.eu/downloads). From the broader perspective, the alignment of bio-based plastics to the objectives of the UN SDGs has been explored through the use of an expert survey. The United Nations (UN) released their Sustainability Development Goals (SDGs) in 2016, as a way to operationalise the journey towards sustainable development taking into account the three dimensions of sustainability (environmental, economic and social) and reflecting society now and in the future. In this survey, 101 experts from academia and industry were asked what level of impact (positive or negative) the current plastic industry has on each of the 17 SDGs. Next, they were asked to consider two future scenarios; (1) better behaviours and (2) increased proportion of bio-based plastic as well as better behaviour, and then to pontificate on the potential level of impact.

As shown by Figure , with the exception of SDG 9, the impact of the current situation was reported to have a neutral to negative impact on all the SDGs, with SDG 13-15 (climate change, life on land, life below water) reporting very negative impacts. Overall, respondents were of the opinion that future scenarios would have a more positive impact when compared with the current situation. However, Scenario 2 marked in green (i.e., with a marked increase in the proportion of biobased plastic) presented a greater opportunity for positive impact when compared with Scenario 1 marked in brown (same proportions of fossil/bio-based plastic – but better behaviour). In addition, regardless of the scenario, respondents were of the opinion that the plastics industry has the most positive impact on SDG 9 (Industry, Innovation and Infrastructure).

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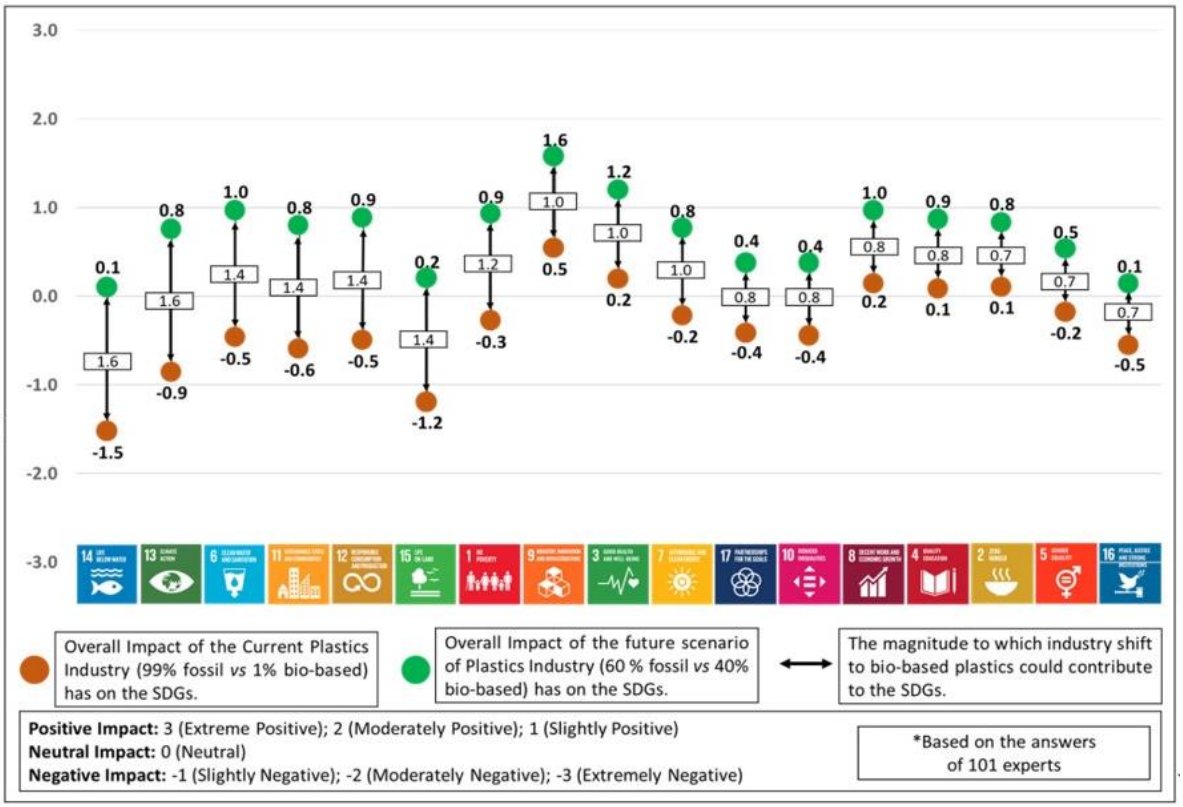

Figure 4: Results from expert survey regarding impact of current and future plastic industry on each of the 17 UN SDGs.

The assessment utilized a gauge scale to understand the impact of plastics on the SDGs, ranging from -3 (Extremely Negative) to +3 (Extreme Positive), with 0 indicating a Neutral impact. Findings from this analysis underscored a significant negative impact of the current industry makeup—99% fossil-based and 1% bio-based plastics—on several critical SDGs. Notably, SDGs related to environmental sustainability, such as SDG 14 (Life Below Water), SDG 15 (Life on Land), and SDG 13 (Climate Action), were among the most adversely affected. This reflects the detrimental consequences of conventional plastic production and usage on natural ecosystems and climate stability.

Conversely, the assessment illuminated a promising shift in the potential future scenario where the industry evolves to comprise 60% fossil-based and 40% bio-based plastics. Experts opined that such a transition would markedly benefit the SDGs, fostering positive outcomes across the board. This shift is particularly advantageous for SDGs that focus on environmental conservation and sustainable resource management, including SDG 14 (Life Below Water) and SDG 15 (Life on Land), as well as SDGs that address broader sustainability challenges like SDG 13 (Climate Action), SDG 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities), and SDG 12 (Responsible Consumption and Production).

This forward-looking analysis not only reinforces the urgent need for a paradigm shift towards more sustainable plastics but also highlights the tangible benefits such a transition can offer in aligning the plastics industry with global sustainability goals. It underpins the BIO-PLASTICS EUROPE project's commitment to fostering a more sustainable plastics economy, one that harmonizes industrial innovation with environmental stewardship and societal well-being.

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4.2.4 Integration with current EU policies

When it comes to integrating or aligning with EU policies, a number of initial steps have been taken. A **policy framework on biobased, biodegradable and compostable plastic** was released in 2022 with the aim of better understanding of the challenges and benefits that arise from the use of biobased and biodegradable plastics. It also sets the conditions needed to ensure that the overall environmental impact (specifically regarding production and consumption) is positive, tries to identify and fill policy gaps, looks to guide future EU policy and tries to support market-based orientation. While the publication of this framework was a positive first step, it is not legally binding. In fact, there is currently no EU law in place applying to biobased, biodegradable and compostable plastics in a comprehensive manner, with only partial objectives in existing directives such as the SUP and Plastic Bag directives.

Within the project strong accent has been given to the stakeholder thoughts on current policy and governance. The outcomes of the workshops conducted are the following:

- The stakeholders noted that while there is a range of existing, and suitable, governance mechanisms already in use, it is the ***lack of conformity across different policy areas that actually create the biggest barriers***.
- The stakeholders noted that having a clear direction of travel (e.g., towards a well-defined circular economy) supported by the ***establishment/maintenance of effective feedback mechanisms*** (where all stakeholders have an active voice) ***should be a priority for current EU policy and governance*** with respect to bio-based/biodegradable plastics and beyond.
- Developing an ***overarching policy framework*** (and preferably an associated time-bound roadmap) would provide a foundation from which strategies and initiatives across the different policy thematic areas can align or "pull in the same direction", rather than contradicting or conflicting with one another.
- Once these foundations have been laid, then focus should turn to educating citizens from a young age the impacts human behaviour can have on the environmental, as well as raising awareness of sustainability issues (including the relative differences when utilising bio-based, biodegradable and/or conventional plastics) within the creative, product design and manufacturing sectors.

In light of these arguments, this whitepaper suggests that bioplastics are often an afterthought within current EU policy and therefore not properly considered or accommodated within evolving policy developments. As such, the European Bioplastic system is not functioning as well as it could be and its contribution to the circular economy is not being fully realised.

5 Solutions

The core ambition of the BIO-PLASTICS EUROPE project has been to develop sustainable strategies and solutions for bio-based products to support the EU Plastics Strategy and a Circular Economy. To achieve this ambition, project partners have been turning knowledge into practice through technical, policy and business-model innovations. The following sub-

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sections will briefly describe the policy, market-based and stakeholder-based solutions that have been developed by the project.

5.1 Policy recommendations

In conjunction with this whitepaper, the BIO-PLASTICS EUROPE project has also released two policy briefs.

The first policy brief focuses on the broader bioplastic system and how well it aligns with the concept of a circular economy. To do that, this first policy brief is based on the 10 critical issues (Figure 5), identified within the project, that may hinder the deployment of the whole bioplastics system, and the results and strategies obtained through both testing and stakeholder engagement activities.

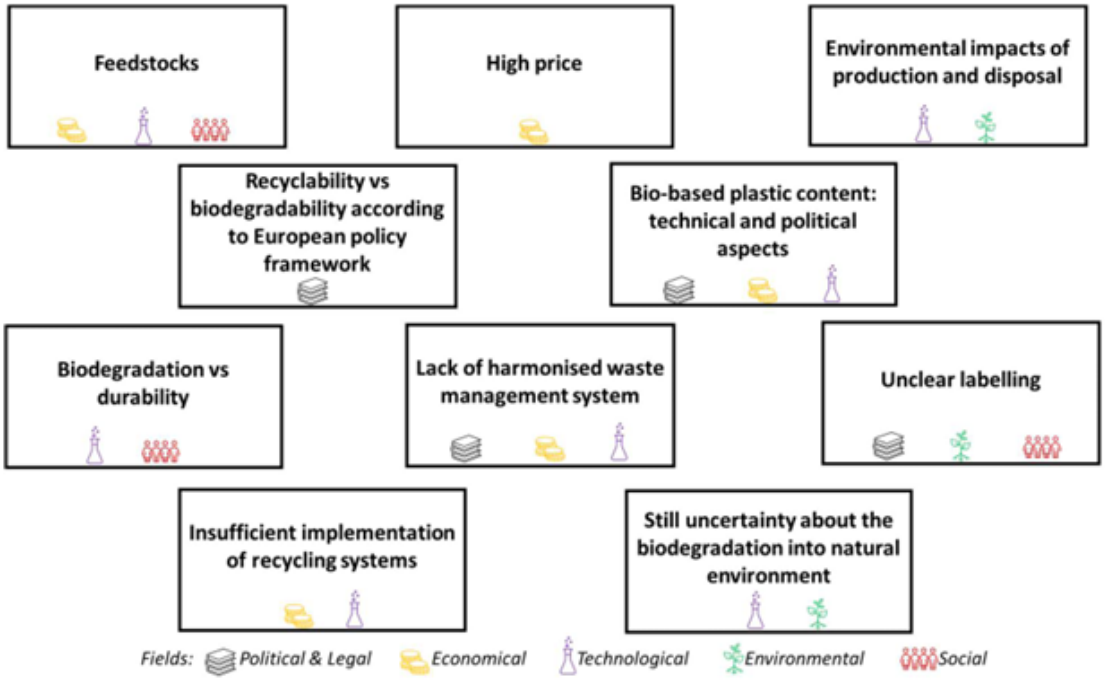

Figure 5: Top 10 critical issues for the bioplastics system

The key recommendations of this policy brief are, as follows;

- Importance of enhanced education and communication to end-users/consumers on benefits of choosing bio-based, biodegradable and compostable plastic products and how to better dispose them.
- Promote further research on the entire bio-based material value-chain system, from production to disposal, with the aim to overcome both technical and economic issues that are still in place.
- Relevant and sensitive toxicity and ecotoxicity tests, for human as well as environmental risk assessment, should be included for bio-based and biodegradable materials. Particularly, for any additives and combinations of additives which are used in the production of both bio-based and biodegradable plastics.

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An overall recommendation targeting the plastic industry companies in terms of their work on improving materials, is that they should include specific tests. For instance, degradation tests, and also rapid degradation test of the material. Investigate how the material properties change both during degradation in waste plants, as well as in the environment.

The second policy brief focuses on two specific markets/applications: Toys (https://amsacta.unibo.it/id/eprint/7221/) and Agricultural Mulch Films (https://amsacta.unibo.it/id/eprint/7385/). This second policy brief is structured around emphasizing the need for systemic changes to enhance sustainability across the value chain. It analyzes the opportunities presented by the adoption of bio-based bio-degradable materials, highlighting among other factors, the importance of multi-stakeholder collaboration in using the new materials.

The brief discusses the economic dimensions of adopting bio-based and biodegradable plastics, including the potential for creating new market opportunities, and it stresses the critical role of consumer awareness and education in driving demand for sustainable products. Furthermore, it highlights the need for clear labelling and certification schemes to inform purchasing decisions.

In addition, an important part focuses on the health and safety implications of bio-based and biodegradable plastics, their impact on soil health and biodiversity in the context of agricultural use, and the use of additives and other hazardous materials for toys.

At the end, the policy brief explores end-of-life scenarios for bio-based and biodegradable plastics, including composting, recycling, and waste management strategies. It advocates for the importance of adequate infrastructure and systems that can effectively manage these materials at the end of their life to minimize the environmental impact.

The key recommendations of the second policy brief in accordance with the multi-stakeholders and experts' priorities, that bio-based plastics have a high potential to contribute to the sustainability of the industry if:

Agricultural mulch films

- Farmers' awareness about the impact of certain practices on the soil and human health is increased.
- Removal, collection, and recycling are ensured.
- Mandatory or voluntary extended producer responsibility schemes in each EU country are established
- Invest in R&D to improve the technical characteristics of biodegradable mulch films. Introduce guidelines for better removal of conventional mulch films from soils.

Toys:

- Eco-design for recycling criteria is better defined.

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- A strict methodology to assess environmental benefits is established.
- Robust communication about product sustainability is introduced.
- Clear information about the bio-based content is given.
- A rigorous assessment of recyclability and biodegradability properties in a range of environments is performed.

5.2 Market-based recommendations

The BIO-PLASTICS EUROPE project has highlighted the potential of bio-based and biodegradable materials in achieving a sustainable economy. However, transitioning towards these materials necessitates concerted efforts across the value chain, including brand owners, transformers, consumers, policymakers, and waste management entities. The recommendations emerging from the brief highlight the importance of developing products that meet the requirements (functional or mechanical) of those created with conventional plastics and achieve a better environmental footprint while being economically viable. For instance, the toys and mulch film industry show how bio-based and bio-degradable plastics can positively impact plastics' use, despite several barriers to their implementation.

It is important to work all the value chain to actualize the market potential of bio-based and biodegradable plastics. An important point is the cost of bio-based and bio-degradable materials, which are significantly higher than traditional plastics. This is a significant barrier from the industry perspective. While it remains a significant concern across the value chain, some factors can bring it down. For instance, Extended Producer Responsibility (ERP) can be an important factor in pushing industrial actors toward adopting these materials. The ERP encourages manufacturers to consider the lifecycle impacts of their products and the total costs of bio-based and biodegradable plastics compared to conventional plastics. By focusing on ERP, the value chain actors can find economic benefits in using bio-based and bio-degradable materials instead of conventional plastics.

Furthermore, developing clear standards and certifications for bio-based and biodegradable materials is crucial in providing the value chain with the assurance of product sustainability and compliance with environmental objectives. This can enhance the marketability of products made from these materials and facilitate their integration into existing and new market segments.

5.3 Other tools and networks

The BIO-PLASTICS EUROPE project has been keen to engage with different stakeholders from across different sectors and industries, as well as the various actors within the product value chain / life cycle. As such, in addition to the policy and market-based recommendations, the project has developed numerous tools, networks and concepts which aim to inform, engage and empower a range of stakeholders.

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5.3.1 BIO-PLASTICS SAFETY PROTOCOL

The BIO-PLASTICS SAFETY PROTOCOL tool is targeted at companies that are looking to introduce either bio-based or biodegradable plastics into their product lines and will help to navigate the safety requirements that are associated with them. The tool allows users to explore different documents that may be relevant in keeping bio-based and biodegradable plastic products safe and sustainable. The tool also includes added product specificity, where the information has been aligned to the product groups targeted within the BIO-PLASTICS EUROPE project – toys, products that come into contact with food and other substances (packaging and cutlery), products used on the land (mulch films and geomembranes), and products used within aquatic environments (fish crates and baits).

Simply put, the BIO-PLASTICS Safety Protocol Tool acts to signpost a range of European and International regulations, standards, etc., as well as relevant certification schemes that the company could consider.

AUDIENCE: COMPANIES AND PRODUCERS OF BIO-BASED AND BIODEGRADABLE PLASTIC PRODUCTS

The BIO-PLASTICS Safety Protocol can be accessed directly through this link (it is best viewed on a computer screen, laptop, or tablet): https://xd.adobe.com/view/2c735ca9-34c2-4b6f-b596-d9afdffbdb84-7920/?fullscreen

5.3.2 SUSTAINABILITY FRAMEWORK FOR BIO-BASED PROJECTS

Sustainability seeks to meet the needs of the present generation, across social, economic, and environmental aspects, without compromising the ability of future generation to do the same. Across different sectors, many frameworks have been developed to engage with or improve sustainability, however comparisons between them can be challenging as frameworks tend to vary by purpose, value, and context. Within European strategy, policy and research, sustainability has been a key theme over the last two decades, where in recent iterations the inclusion of circular economy principals and the exploitation of the bioeconomy have come to the forefront. Within this, the development and uptake of bioplastics (namely those that are bio-based and/or biodegradable) is one avenue that the European Commission has been keen to explore.

Despite a number of sustainability frameworks that have already been developed, there is currently no frameworks available to ensure the sustainability of bio-based products. Furthermore, recent projects have tended to focus largely on technical performance and economic feasibility, highlighting a lack of clear consideration for all aspects of sustainability. To address this gap, the BIO-PLASTICS EUROPE project has developed the 'Sustainability Framework for Bio-based Plastic Projects' to ensure that all three dimensions of sustainable development are fully considered by future projects.

AUDIENCE: RESEARCH AND ACADEMIA (PARTNERS OF NEW BIO-BASED PROJECTS)

The BIO-PLASTICS EUROPE Sustainability Framework for bio-based plastics can be downloaded from the projects website: https://bioplasticseurope.eu/downloads

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5.3.3 WASTE MANAGEMENT HANDBOOK

The "Waste Management Handbook" is a comprehensive guide developed as part of the BIO-PLASTICS EUROPE project, which focuses on sustainable solutions for bio-based plastics on land and sea. This handbook is specifically designed to address the impacts of bio-based and biodegradable plastics (and additives) on existing waste management frameworks. The primary goal of this handbook is to facilitate the development of sustainable strategies and solutions for bio-based plastic products, as well as to promote circular innovation across the entire bio-based plastics system.

Intended for a wide range of stakeholders, the handbook is particularly useful for decision-makers at national and regional levels, business representatives, scientists, and members of society interested in environmental issues. It covers key topics including the concepts of bio-based and biodegradable plastics, Life Cycle Assessment, and Circular Economy principles. The handbook also provides an in-depth analysis of the impact of bio-based, biodegradable, and compostable plastics on waste management technologies and systems, alongside an examination of relevant legal and policy frameworks. Additionally, it includes promising business cases from project partner countries, offering practical examples and insights.

In essence, the "Waste Management Handbook" serves as an essential resource for those looking to understand and navigate the complexities of waste management in the context of bio-based and biodegradable plastics. Its comprehensive coverage of technical, legal, and practical aspects makes it a valuable tool for a broad audience engaged in addressing the challenges and opportunities presented by plastic pollution and waste management.

AUDIENCE: DECISION-MAKERS AT NATIONAL AND REGIONAL LEVELS, BUSINESS REPRESENTATIVES, SCIENTISTS, AND MEMBERS OF SOCIETY INTERESTED IN ENVIRONMENTAL ISSUES.

Copies of the handbook are available for free download at the following address: https://bioplasticseurope.eu/media/pages/downloads/public-deliverables/883f88dfc0-1679641878/bpe-handbook_public.pdf

5.3.4 POLICY2PROJECTS CONCEPT

The concept Projects2Policy has been created jointly by BIO-PLASTICS EUROPE and GLAUKOS projects, who emphasized the need for bridging the gap in information flow between projects and the EU policy makers. The concept was focused on grouping EU projects and discussing the challenges while creating joint recommendations coming from the projects to the EU.

The BIO-PLASTICS EUROPE team and the team from the GLAUKOS project organized a workshop followed by an online event on policy. The workshop took place online on 3rd November 2022 under the title, “Unlock the potential of bio-based and biodegradable plastics: challenges to be addressed”. A discussion round with 4 topics with 4 questions each

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was opened, to collect the participants' inputs on relevant bio-based plastics and policy topics. In total, over 70 participants took part in the workshop, **representing 49 relevant EU projects**. The results from the workshop have been further used as a basis for an open discussion with the EU policy officers who joined for the upcoming online event on 23rd November 2022, which was attended by more than 50 participants, 12 of which were EU policy officers. The four topics covered were LCA of bio-based vs conventional plastics, End-Of-Life Options Raising Awareness and Stakeholder Engagement and Projects contributions to EU Policies.

The workshop sparked some lively discussions between policy officers and projects on **how to shorten the gap between projects and policies and how to increase opportunities for mutual learning and exchange**. The policy officers expressed a general need for clear scientific facts to form based policy decisions. The need for a mutual language was expressed by both sides.

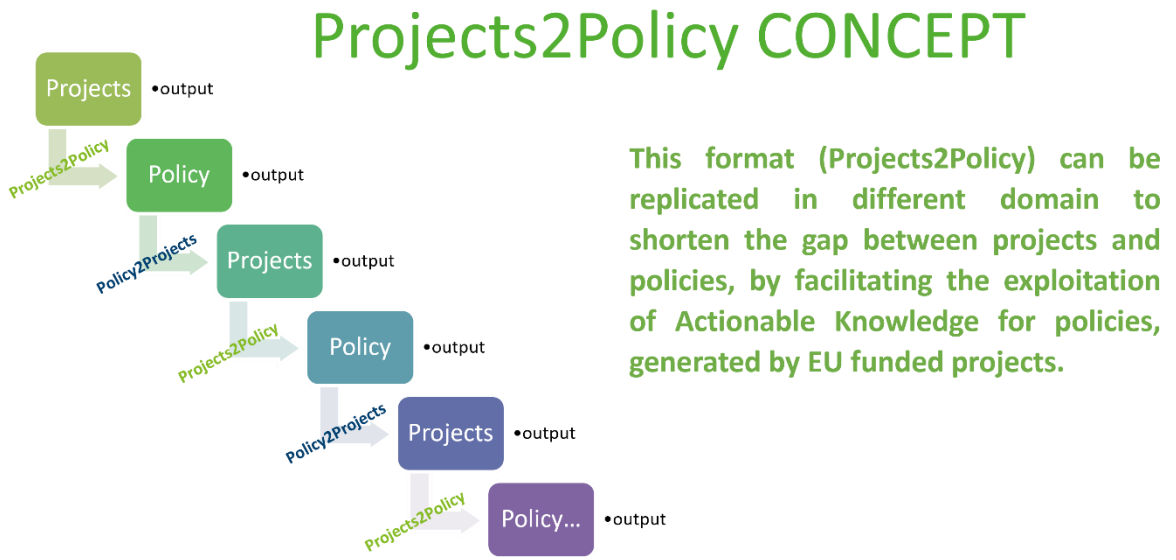

Figure 6: Projects2Policy Concept

AUDIENCE: EU PROJECT COODINATORS AND PARTNERS, POLICY MAKERS

More information about the concept can be found on the project`s website: https://bioplasticseurope.eu/downloads.

5.3.5 HISCAP NETWORK

The "Network of Historic Cities against Plastic Waste" (HISCAP) is a close-knit group of municipal authorities pledging against plastic waste and implementing project results and recommendations towards bio-based plastics. This engagement facilitates the uptake of project results by civil society and public authorities.

This network congregates historical cities from Europe, whose aged infrastructure makes them especially vulnerable to the many problems caused by plastic pollution. The network

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fosters the sharing of cooperative knowledge of Best Practices and Lessons Learned among the participating cities and will address many problems plastics pose to their environment and infrastructure, with the specific purpose of pursuing the use of bio-based plastic alternatives.

AUDIENCE: PUBLIC / LOCAL AUTHORITIES

More information about the HISCAP can be found here: https://bioplasticseurope.eu/hiscap

5.3.6 EBRN NETWORK

The European Bioplastics Research & Networking (EBRN) network is an active community of researchers, executives, enthusiasts and activists gathered to discuss and spread cutting-edge knowledge in the field of bio-based plastics. BIO-PLASTICS EUROPE aims to provide strategic networking and research, coordinating knowledge across Europe, catalysing new ideas and rapid solutions across the research and innovation landscape.

EBRN congregates representatives from universities, research institutions and enterprises interested in research bio-based and biodegradable plastics research. This is a technical network, encompassing for example engineers, biologists, planners and economists, which focuses on the technicalities of bio-based plastics development, applications and uses. Regular meetings and relationships with other organisations in this field help to reach synergies and avoid duplications.

AUDIENCE: ACADEMIA, RESEARCH AND INDUSTRY

The EBRN network is delivered via LinkedIn: https://www.linkedin.com/groups/8848234/

5.3.7 SOCIAL MEDIA FILTER

In light of the global challenges related to the COVID-19 pandemic, the project chose to create a social media filter that would facilitate the sharing of knowledge concerning the protective potential of face masks as well as the environmental impacts that may arise from the inappropriate disposal. The developed filter (available on Instagram) provides a visually experience of a science-based comparison of different face masks available in the market, based on level of protection and biodegradability.

AUDIENCE: GENERAL PUBLIC, STUDENTS

The explanation and the filter can be find here: https://bioplasticseurope.eu/news-events/bio-plastics-europe-releases-instagram-filter-protection2

5.3.8 PI VIRTUAL ENGAGMENT TOOL

White Paper: Virtual Engagement Tool for Sustainable Disposable Cutlery**

What is it and what is it for?

The Virtual Engagement Tool for Sustainable Disposable Cutlery, an integral part of Prospex Institute's e-Lab, represents an innovative digital platform dedicated to exploring the

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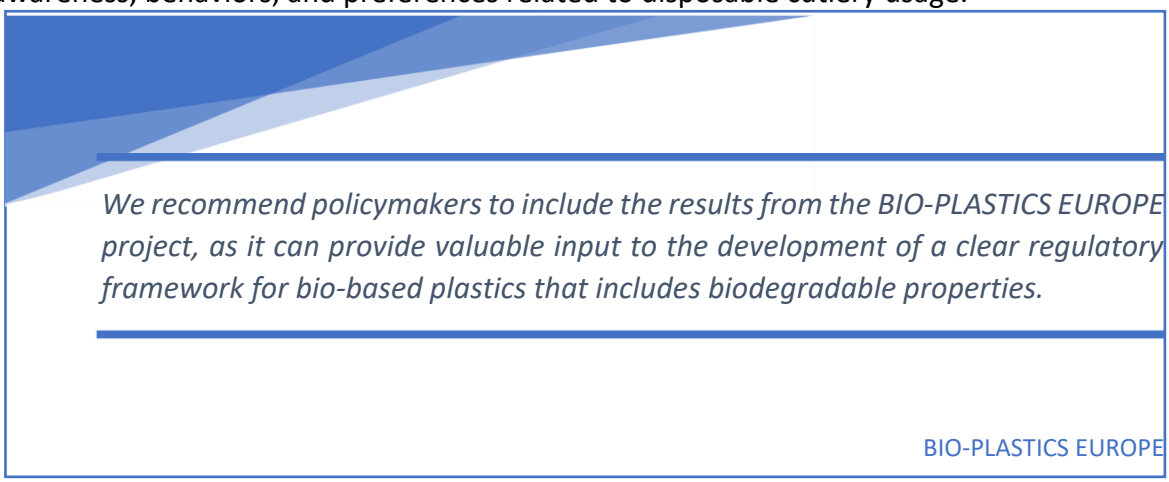
challenges and solutions surrounding disposable cutlery. Focusing specifically on Single-Use Plastics (SUP) cutlery, the tool serves as a comprehensive resource for gathering insights into awareness, behaviors, and preferences related to disposable cutlery usage.



This tool serves as a platform for mutual communication. Firstly, it provides a space for participants from the general public to contribute their perspectives on disposable cutlery, enriching our understanding of their awareness, behaviors, and preferences. Secondly, it acts as an educational platform, offering information on why SUP cutlery is a problem and presenting sustainable alternatives. The gamification features embedded within the tool make the learning experience interactive and engaging, encouraging active participation and knowledge retention.

While the tool has recently been launched, its design ensures a sustained impact beyond the project's end. Prospex Institute is committed to maintaining an ongoing engagement with stakeholders. The platform will continue to serve as a catalyst for dialogue and collaboration even as the BIO-PLASTICS EUROPE project concludes. This enduring commitment will further fortify the tool's role in shaping a more sustainable future for disposable cutlery.

Audience: General Public

Tailored for individuals from diverse backgrounds, the tool is designed to engage the general public in a collective effort to address the challenges posed by disposable cutlery. Through gamified features, it ensures that users not only learn about the issues surrounding SUP cutlery but actively participate in finding solutions. By being part of Prospex Institute's e-Lab, the tool emphasizes inclusivity, inviting a broad audience to contribute to shaping sustainable practices in disposable cutlery usage.

Where Can I find it?

The Virtual Engagement tool can be found on the Prospex Institute's e-Lab website following this link; https://bioplastics.prospex-institute.org/#BIOPLASTICS_INTRO or by scanning the QR code:

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6 Conclusions

The recommendations are:

- Importance of enhanced education and communication to end-users/consumers on benefits of choosing bio-based, biodegradable and compostable plastic products and how to better dispose them.

- Promote further research on the entire bio-based material value-chain system, from production to disposal, with the aim to overcome both technical and economic issues that are still in place.

- Relevant and sensitive toxicity and ecotoxicity tests, for human as well as environmental risk assessment, should be included for bio-based and biodegradable materials. Particularly, for any additives and combinations of additives which are used in the production of both bio-based and biodegradable plastics.

- An overall recommendation targeting the plastic industry companies in terms of their work on improving materials, is that they should include specific tests. For instance, degradation tests, and also rapid degradation test of the material. Investigate how the material properties change both during degradation in waste plants, as well as in the environment.

- Turn focus to educating citizens from a young age the impacts human behaviour can have on the environmental, as well as raising awareness of sustainability issues (including the relative differences when utilising bio-based, biodegradable and/or conventional plastics) within the creative, product design and manufacturing sectors.

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