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BIO-PLASTICS EUROPE

Strategies for circular innovation of the whole bio-plastics system

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ABSTRACT

This document presents a set of replicable strategies for circular innovation of the whole bio-plastics system. To do this, the identification, evaluation and selection of these strategies have been conducted through a circular and continuous process, which had involved the interaction with many different stakeholders and stakeholder groups. This document is useful for the exploitation and replicability of the defined strategies.

KEYWORDS

Circular innovation, bio-plastic system, replicable strategies, critical issues, SWOT analysis, stakeholder engagement, innovation workshop, Design Thinking methodology

DISCLAIMER

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List of Abbreviations and Acronyms

Abbreviation	Meaning
AMF	Agricultural Mulch Film
BPE	BIO-PLASTICS EUROPE
C	Cutlery
D[n.n.]	Deliverable [number]
EoL	End-of-Life
EPR	Extended Producer Responsibility
EU	European Union
FB	Fishing bait
FC	Fish crate
MG	Marine Geomaterial
MMU	Manchester Metropolitan University
PBS	Polybutylene succinate
PESTEL	Political, Economic, Social, Technological, Environmental, and Legal
PET	Polyethylene terephthalate
PHAs	Polyhydroxyalkanoate polymers
PHB	Polyhydroxybutyrate
PHBV	Poly(3-hydroxybutyrate-co-3-hydroxyvalerate)
PLA	Polylactic acid
PP	Polypropylene
PS	Polystyrene
SUP	Single-Use Plastics
SWOT	Strengths, Weaknesses, Opportunities and Threats
T[n.n.]	Task [number]
TICASS	Tecnologie Innovative per il Controllo Ambientale e lo Sviluppo Sostenibile scrl
TOWS	Threats, Opportunities, Weaknesses and Strengths
WP	Work Package

Executive Summary

This report, which presents the outcomes of desk-based and stakeholder engagement activities undertaken as part of Work Package 5 – Pre-normative research and field tests (Task 5.3 – Development of strategies for circular innovation of whole bio-plastics system) of the project "Developing and Implementing Sustainability-Based Solutions for Bio-Based Plastic Production and Use to Preserve Land and Sea Environmental Quality in Europe (BIO-PLASTICS EUROPE)" under the H2020 Grant Agreement No. 860407.

The objective of this deliverable is to develop replicable strategies for circular innovation of the whole bio-plastics system, building on a shared vision and enhancing cooperation between different stakeholders. Task 5.3 aimed to evaluate the best strategies in the view of mapping, destination, end-of-life scenario, cross lifecycles with conventional plastics and critical issues.

This document has been delivered to the European Commission in July 2023 (M46).

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1 Introduction

1.1 Scope of the deliverable

This deliverable aims to present a comprehensive framework for the identification and evaluation of replicable strategies to overcome the obstacles hindering the deployment of the whole bio-plastics system. In this report, the “whole bio-plastics system” is defined as the entire value chain of the bio-plastic products, including material and application production, use and end-of-life scenarios. A specific focus has been placed on the bio-based and biodegradable plastic materials studied within the BIO-PLASTICS EUROPE project, however in some cases the strategy development process was addressed to all kinds of bio-plastic materials, not only bio-based **and** biodegradable. In these cases, the general term *bio-plastics* was used.

The process begins with a thorough classification of bio-based and biodegradable plastics based on their target applications and optimal circular waste management strategy. By understanding the specific characteristics and requirements of different types of bio-plastics, we can tailor strategies, accordingly, ensuring their optimal use and management within a circular economy framework.

To pinpoint the most critical issues impeding the progress of the bio-plastics system, an assessment of the top 10 key challenges was conducted. This evaluation serves as a foundation for further analysis and the development of effective strategies.

However, the identification of strategies cannot be solely based on theoretical frameworks. To ensure their practicality and relevance, a stakeholder consultation process was integrated into the methodology. This inclusive approach involves engaging with various stakeholders, including municipal authorities, producers, marketing experts and waste management bodies. Their diverse knowledge and experiences are harnessed to evaluate, select, and refine the most promising replicable strategies, ensuring alignment with a circular approach.

Once the best replicable strategies were defined, a case study approach was employed to evaluate their feasibility in a target area where citizens could be effectively involved. To ensure the most replicability, the selection of the case study area considered more than just the physical location, where access to a large number of interested citizens also played a factor. As such, the Village areas of the “Ocean Live park” was selected. This event took place in Genoa from 24th June to 2nd July 2023, as part of “The Ocean Race Genova -The Grand Finale 2022-23” and attracted more than 200.000 participants. By analysing real-life scenarios, the potential challenges and opportunities associated with implementing the selected strategies were examined, considering factors such as regional infrastructure, regulatory frameworks, and market dynamics. This empirical evaluation allows for a comprehensive understanding of practical implications and the impacts of the identified strategies; facilitating informed decision-making and the potential for successful adoption.

In summary, this deliverable sets out a structured and comprehensive methodology for the identification and evaluation of replicable strategies for circular innovation of the entire bio-plastics system.

1.2 Structure of the deliverable and methodology

With the aim of defining the replicable strategies to address the circular innovation of the whole bio-plastics system, a strategy development process has been followed.
Continuous and circular in nature, this process has included the following phases:

- Environment analysis,
- Identification, evaluation, and selection of strategies,
- Evaluation of defined strategy applicability,
- Exploitation of the defined strategies.

Based on this process, the key components of this deliverable are structured as follows:

1) **Environment analysis** - This section provides the results of the environment analysis, identifying important advantages, disadvantages, critical issues, and opportunities that can hinder or support the goal achievement.
   It includes:
   - **Classification of bio-based and biodegradable plastics,** where an overview of different types of bio-based and biodegradable plastics is provided with categorization based on target application and potential for circular waste management. Here, the aim was to understand the specific characteristics and requirements of each type of bio-based and biodegradable plastic, which will inform the development of strategies later in the deliverable.
   - **Identification of critical issues**, where the 10 most critical issues hindering the deployment of the entire bio-plastics system are identified.
   - **SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis implementation**: where critical issues were identified using an approach that assesses the internal strengths and weaknesses of the system, as well as the external opportunities and threats it faces. This enables a comprehensive understanding of the challenges that need to be addressed.

2) **Identification, evaluation, and selection of replicable strategies -** This section describes the steps followed to identify and select the replicable strategies and the results obtained through this path.
   - **Stakeholder consultation through interviews**: to enhance the relevance and practicality of the strategies, this section involves engaging with relevant stakeholders. Interviews are conducted as part of Task 5.2 with key stakeholders such as European associations, producers, marketing experts, and waste management companies (for more information on the process and results of this stakeholder engagement phase, please see Deliverable D5.2 – *Technical Report: biodegradable and compostable solutions supporting policymaking in research, innovation and technology with focus on the EU Plastic Strategy*). These interviews provide valuable insights into the perspectives, experiences, and knowledge of the stakeholders, enriching the strategy development process.
   - **Stakeholder consultation using the Design Thinking methodology**: an innovative workshop incorporating the Design Thinking strategy was conducted and involved stakeholders from various backgrounds. The workshop sought to facilitate brainstorming, ideation, and evaluation of strategies based on a circular approach. Through an iterative and collaborative process, the workshop aimed to identify and

refine the best replicable strategies that have the highest potential for successful implementation.

- **Identification of strategies using the TOWS (Threats, Opportunities, Weaknesses, Strengths) matrix**: building on the SWOT analysis and stakeholder consultation results, the TOWS matrix aligns issues identified by the SWOT analysis with corresponding strategies that leverage strengths, mitigate weaknesses, seize opportunities, and counter threats. This step ensured that the strategies developed were well-aligned with the specific challenges and opportunities identified previously.

3) **Evaluation of defined strategy applicability -** Once the best replicable strategies were defined, this section involved conducting case studies to evaluate the feasibility of implementing these strategies in a large-scale local event. Real-life scenarios were analysed considering factors such as regional infrastructure, regulatory frameworks, and market dynamics. This evaluation provides valuable insights into the practical implications and impacts of the identified strategies and will enable informed decision-making.

4) **Exploitation of the defined strategies -** In the view of ensuring that the selected strategies can be applied and replicated, the results will be made available for the project exploitation phase. One of the main means of exploitation delivery will be Task 5.4, providing “policy briefs” in a form that allows for efficient feedback into policymaking in research, innovation and technology.

By following this structured approach, this deliverable aims to provide a comprehensive understanding of the circular innovation of the entire bio-plastics system. The combination of classification, issue identification, strategy development, stakeholder engagement, and feasibility evaluation ensure that the framework developed for driving sustainable solutions in the field of bio-plastics is both robust and practical.

2 Environment analysis

Internal and external environment analysis is fundamental to identify advantages, disadvantages, critical issues, and opportunities that can hinder or support the goal achievement. Therefore, an analysis of current strengths, weaknesses, opportunities, and issues to develop the whole bio-plastics system in a circular economy perspective was conducted.

2.1 Classification of the different bio-based biodegradable plastics

At first, with the aim of having a comprehensive picture of the bio-plastics system, a classification of the different bio-based and biodegradable plastic materials in the view of their intended use and waste management strategy has been carried out.

Inputs from other Work Packages (mainly WP3) and from literature [1, 2] were taken into account to elaborate the classification.

Bio-plastic materials are generated from several sources, that can be bio-based and fossil-based. The biodegradability[1]of plastic materials is not connected to the bio-based origin of the compound, where some bio-based plastics are not biodegradable while other fossil-based plastics can be. Notwithstanding the complexity surrounding the classification of all bio-plastics, the classification presented by this report focuses only **on bio-based and biodegradable materials**. The decision to focus on this sub-set of bio-plastic materials was underpinned by the objectives and goals of the BIO-PLASTICS EUROPE project, which is to study and test different compounds in order to find materials with these characteristics (i.e., biobased and biodegradable).

A classification of bio-based and biodegradable plastics based on their origin resource is illustrated by Figure 1, with a more detailed explanation of both provided below. They are polymers: large molecules composed of repeating structural units called monomers. These monomers are covalently bonded together in a chain-like fashion, forming long and flexible macromolecules. Polymers can be classified into two main categories based on their nature:

1) synthetic polymers: artificially created through chemical reactions, starting with monomers derived from petrochemicals or other sources.
2) natural polymers: these polymers occur naturally in various biological systems and can be harvested or extracted.

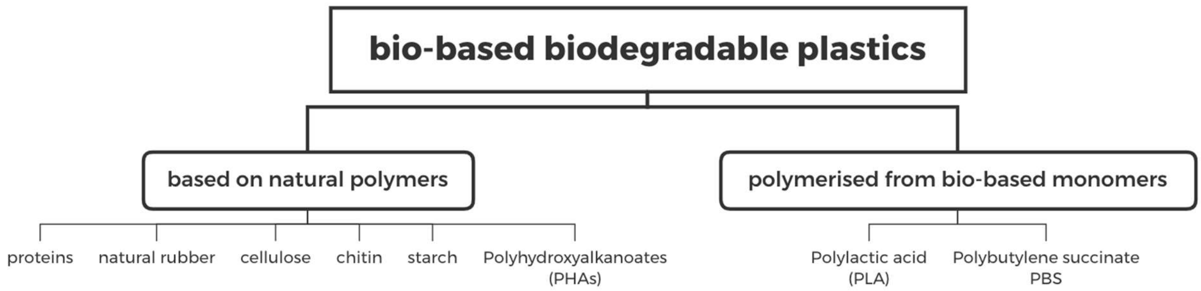

Figure 1 Overview of bio-based and biodegradable plastics.

2.1.1 Materials based on natural polymers

A wide variety of bio-based and biodegradable plastics based on natural polymers exists, but only a few have been put into major commercial production.

The first natural polymers to be used were **natural rubber**, **cellulose**, **starch** and **casein**.

Natural rubber was originally derived from latex, a milky colloidal suspension found in special rubber trees. Its first use was cloth waterproofed with unvulcanised latex, then vulcanization of natural rubber with sulphur was discovered in 1839 improving elasticity and durability.

Cellulose is the most abundant natural polymer on earth. Its main origin is plant material (wood, cotton, flax, jute, sugarcane, cereals, etc.) where cellulose is an important structural

[1] Biodegradability is the potential for a polymeric material to undergo a biodegradation process (i.e., breakdown of an organic compound by microorganisms in the presence of oxygen to carbon dioxide, water, mineral salts and new biomass, or in the absence of oxygen to methane, mineral salts and new biomass).

component of plants. Cellulose can also be synthesized from acetic acid bacteria. The bacterial cellulose is extremely pure, unlike cellulose from plants, which is typically mixed with lignin, hemicelluloses, and pectin. The main sources of cellulose for industrial processes are wood and cotton. Cellulose is the main component of paper, cardboard, and textiles made of cotton, flax, or other plant fibres. It is also used in packaging applications: for example, cellulose acetate is used in cellophane production.

Starch is produced during photosynthesis, and acts as a food reserve where it is found mainly in the roots, stalks, and seeds. Starch has been used for centuries as glue for paper and wood and as gum for textile sector. Starch based materials are usually made from crops such as corn, wheat, potato, barley, sorghum, tapioca, and rice. Several refining steps are needed to release and purify starch from its natural resources. Starch has gained much popularity due to its characteristics: wide availability, low cost, and total biodegradability without toxic residues. In the process of composting, starch rapidly biodegrades in many different environments. However, natural starch is unsuitable for most applications due to poor mechanical properties (e.g., brittleness) and hydrophilicity; in order to overcome these issues and improve its characteristics the starch is frequently blended with more waterproof polymers, or it is chemically modified. Products based on starch and its derivatives include: flexible and rigid packaging; bags (e.g. shopping bags and bags for biowaste collection); agriculture and horticulture applications (e.g., mulching film, plant pots); hygiene and cosmetics products (e.g., nappies, sanitary products).

Chitin is the second most abundant organic materials on earth, it is a polysaccharide found in the exoskeleton of arthropods or in the cell wall of fungi and yeasts. The main commercial source of chitin comes from crab and shrimp shells; however, it isn’t a thermoplastic polymer (causing processing issues), and it is insoluble in almost every solvent, thus there are very few applications of it. On the contrary, **chitosan**, a chitin derivative, features good solubility in acidic aqueous media and it can be used to prepare hydrogels, films, fibres, or sponges. Most of these products are made for biomedical applications. In addition, chitosan shows interesting antimicrobial properties and considerable research has been conducted for incorporating chitosan in several other applications, including textiles and food packaging.

Proteins are natural polymers composed of long chains of smaller subunits called amino acids. Proteins are inextricably linked to life because they are responsible for facilitating thousands of biochemical reactions in the metabolisms of living cells due to their action as enzymes. The most prominent natural proteins used in technical applications are **casein**, **soy**, and **collagen**. Casein is an early bio-based plastics; it is produced from milk proteins and is still used today for paints and glues. Collagen is the main component of constitutive tissue like tendons, ligaments, and skin in mammals and it was used for thousands of years as glue. Hydrolysed collagen[2] is known as water-soluble hydrocolloid gelatine, which is used primarily in food. Nowadays, technical uses of collagen include a range of medical applications. In general, protein-based plastics have attractive gas barrier properties and can replace conventional plastics in food packaging applications.

Polyhydroxyalkanoate polymers (**PHA**) are naturally produced by bacterial fermentation of plant sugars or lipids and are a wide group of bio-polymers. Some of the most well-known PHA

[2] Hydrolysed collagen is a form of collagen that has undergone a process called hydrolysis. Hydrolysis is a chemical process in which collagen is broken down into shorter fragments, resulting in smaller collagen peptides.

compounds are **Polyhydroxybutyrate (PHB) and poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV)**. PHAs are gaining attention among biodegradable polymers due to their promising properties: they can be produced by a large number of microbial species (approximately 250 different bacteria were found to produce PHA), and they can also be biodegraded by many microorganisms under a broad range of environmental conditions. In addition, unlike other bio-polymers, PHAs have good thermo-mechanical and barrier properties making PHAs valuable for various applications as single-use packaging, food packaging, agriculture, hygiene and cosmetic products and biomedical devices. PHB and PHBV are compatible with the blood and tissues of mammals and human body can reabsorbs it. As such they could be used in applications such as surgical sutures, microcapsules or materials for cell and tablet packaging (such as blister packs). However, PHA also have some weaknesses such as low thermal stability, brittleness and difficulty in processing. In addition, the spread of PHAs is still limited due to the elevated cost and the use of refined/food competing feedstock. Therefore, different research studies are ongoing regarding the improvement of the yield of PHA by genetic modification of the bacteria or through the use of waste (different organic waste streams from agriculture, food industry, municipal waste, or wastewater) for their growth.

2.1.2 Materials polymerised from bio-based monomers

There is wide variety of bio-based molecules available for producing polymers by classical chemical polymerization reactions.

Polylactic Acid (PLA) is a thermoplastic material formed in the process of the chemical polymerization of lactic acid, a common organic acid. The latter is produced via the fermentation of glucose, which can be obtained from various resources such as sugarcane, corn starch, and tapioca. PLA is transparent and has good mechanical properties, similar to polyethylene terephthalate (PET) and polystyrene (PS). It is not soluble in water, but unstable in the presence of halogenated hydrocarbons. PLA became the first polymer from renewable resources to be produced at industrial level. The main use of PLA has been packaging. In addition, it is currently used for bottles, cutlery, disposable tableware, textiles, hygiene products (nappies) and agriculture applications.

Polybutylene succinate (PBS) is mainly produced from fossil-based monomers, but it can also be produced from bio-based monomers or a combination of them. PBS shows properties comparable to polypropylene (PP) and it is used for different applications: packaging films, shopping bags, and sheets, plant pots, hygiene products and food contact products.

2.1.3 Summary of bio-based biodegradable plastics

A summary of the classification of the bio-based biodegradable plastics is reported in Table 1.

Table 1. Classification of bio-based biodegradable plastics.

Material Name (abbreviation)	Application
PROTEINS	Paints Medical applications Food packaging

NATURAL RUBBERS	Automotive sector Adhesives and coatings Clothing
STARCH	Packaging Bags Agricultural applications Hygiene and cosmetics products
CELLULOSE	Packaging
CHITIN	Biomedical applications Textiles Food packaging
POLYHYDROXYALKANOATE (PHAs)	Single use packaging Food packaging Agriculture applications Hygiene and cosmetic products Biomedical applications
POLYLACTIC ACID (PLA)	Packaging Agricultural applications Hygiene products Textiles
POLYBUTYLENE SUCCINATE (PBS)	Packaging Bags Agricultural applications Hygiene products Food contact products

All the bio-based plastic materials listed in Table 1 are biodegradable and, the end-of-life scenario can include composting, anaerobic digestion, or biodegradation in the natural environment according to different applications: e.g., mulch films should be left in the soil, aquatic applications should be left in the sea, while packaging or cutlery could be sent to composting or anaerobic digestion plant. In addition, some materials such as cellulose, chitin, chitosan or PHAs are easily biodegradable, while other ones, such as PLA, are compostable at higher temperature (higher than 60°C) and must be treated in industrial composting plants.

Furthermore, it is important to keep in mind that, often, additional components such as fillers (inorganic or organic), pigments, lubricants, inhibitors of oxidation, etc. are included into bioplastic products in order to improve their properties. A material continues to be biodegradable and compostable if **no more than 5%** of **non-biodegradable** additives are added (according to standard EN 13432[3]). The standards for biodegradable and compostable plastics require the testing of all additives that were used in the production of the final product: none of the components should have a negative effect on the composting process or on the environment and they have to be non-toxic.

BIO-PLASTICS EUROPE project focused its studies on the materials showed in Table 2, with the aim to test and improve their biodegradability, maintaining durability and performance features.

[3] *EN 13432:2000* standards for industrially compostable packaging applications

Table 2 Bio-based biodegradable materials tested within BIO-PLASTICS EUROPE project and their target applications.

Material Public name	Polymeric matrix	Target Application
BPE-C-PLA	PLA-based compound	Cutlery
BPE-AMF-PLA		Mulch Films
BPE-RP-PLA		Rigid packaging
BPE-MG-PLA		Marine Geomaterial
BPE-FC-PLA		Fish Crates
BPE-SP-PBS	PBS-based compound	Soft packaging
BPE-T-PHBV	PHBV-based compound	Toys
BPE-FB-PHBV		Fishing Bait

2.2 Definition of critical issues hindering valorisation, development and diffusion of bio-plastics

To develop replicable strategies that would favour the entire system of bio-based and biodegradable materials according to a circular economy perspective (the main goal of Task 5.3), it is essential to identify the most critical issues that may hinder it.

To do this, information was gathered from activities carried out in **other Tasks and WPs** (i.e. Task 5.2, WP4 and WP8) of BIO-PLASTICS EUROPE project (namely, D5.7-*Preliminary Technical Report: Biodegradable and compostable solutions supporting policymaking in research, innovation, and technology with focus on the EU Plastic Strategy*; D4.3- *Handbook on the impacts of bio-based and biodegradable plastics (additives) on existing waste management frameworks;* D8.5-*Report on Definition and Evaluation of Business Scenarios, Preliminary*), **European documents** and the wider **literature**. In addition, a discussion with other project partners involved in policy activities was conducted in order to determine a shared definition within the project of the most critical issues.

The selection of critical issues focused on the applications studied within the project has been prepared identifying for each application the correspondent relevant issues: some of them, in fact, can change for different applications.

The most 10 critical issues identified can be categorised across different fields: political, economic, technological, environmental, and social. A summary of these issues with the related fields is reported in Figure 2, with a description provided in the following paragraph (2.2.1).

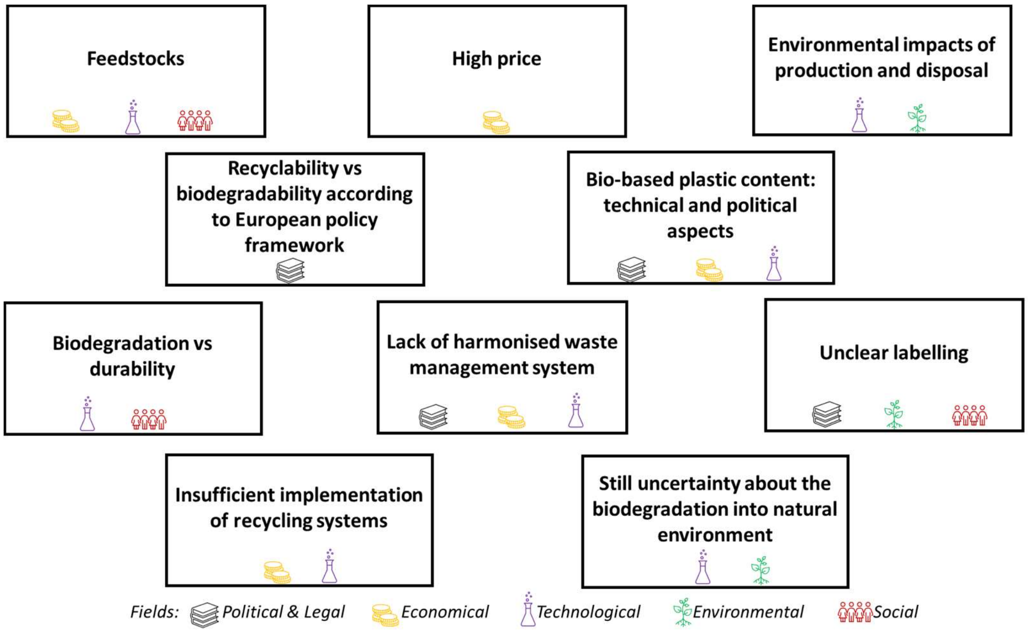

Figure 2: Summary of the 10 most critical issues.

2.2.1 Critical issues description

Feedstocks
Currently, bio-based and biodegradable plastics are derived mainly from food crops, competing for agricultural land with food products and making producers highly dependent on world market prices for these crop (e.g. corn and sugarcane) (*Deliverable 8.5*).

The use of alternative second and third generation feedstocks[4] are still at research and development level; however great effort is taking place in that and bio-plastic production from new feedstocks can also be economically possible in the near future.

High price
At the moment, conventional plastics can be produced at lower prices than bio-based and biodegradable plastics (*Deliverable 8.5*). High costs of production processes and the fluctuating nature regarding the price of raw materials can significantly impact market growth [3].

Environmental impacts of production and disposal
Even if the production of bio-based biodegradable plastics can reduce the use of fossil resources, it would also require the extensive use of fertilizers and pesticides. The use of such products can cause detrimental effects such as soil acidification and eutrophication of water courses. Additionally, if biopolymers are created through production processes that require large quantities of toxic compounds (such as methanol in alcoholysis), the disposal of such material can lead to many environmental side effects [3].

Regarding the environmental impact related to bio-based and biodegradable plastics disposal, these materials can release microplastics potentially less harmful than conventional

[4] *Second generation feedstocks*: lignocellulosic gained from non-food crops or as by-products from the cultivation of food crops. *Third generation feedstocks*: feedstock extracted from a range of substrates like whey, industrial and municipal waste or algae.

microplastics. However, at that stage, this hypothesis is based on a limited number of studies and general assumptions, thus more dedicated research is needed, especially for products that are left on the open environment such as mulch film and aquatic applications [4]. In addition, potentially toxic additives can be released (*Deliverable 4.3*).

Recyclability vs biodegradability according to European policy framework
Acknowledging a lack of legislation specifically targeted towards bio-based and biodegradable plastics, the European Commission is working to overcome this, and associated, issues in a comprehensive manner (*Deliverable 5.7*), where the need for the harmonization of definitions and terminology has been prioritised (*Deliverable 4.3*).

In light of this, the European Commission has developed a comprehensive policy framework on the sourcing, labelling and use of bio-based plastics, as well as on the use of biodegradable and compostable plastics. The *EU policy framework on bio-based, biodegradable and compostable plastics* is now complete and launched with the release of a European Communication, which was published in November 2022 [5]. However, while the policy frameworks goes someway to harmonise the sourcing, labelling and use of bio-based biodegradable plastics, it also aligns with existing EU strategy, whereby to reduce the environmental impact of plastic products, the promotion of recyclable plastics has been prioritise rather than biodegradable plastics.

To illustrate, the European Communication published in 2022 highlights the need to limit the use of biodegradable plastics in the open environment to select material and applications only. With regard to the material, full biodegradability must have been proven below a specific and evidence-based timeframe in order to avoid environmental harm. Similarly, the use of bio-based and biodegradable plastics should be limited to specific applications for which reduction, reuse or recycling are not feasible.

In addition, the European Communication states that when bio-based and biodegradable plastics are used in relatively short-lived applications such as food and beverage packaging, the resources used to produce these products are rapidly lost. Substituting conventional plastics by biodegradable plastics risks slowing down the development of circular economy solutions based on reducing waste and reuse of such products. It also risks disincentivising designs to recycle plastics to keep materials in the loop for as long as possible, as well as the use of more sustainable alternatives that do not contain plastics.

This aligns with other policies, for example in relation to the Packaging and Packaging Waste Regulation revision[5], where the main focus is on reusability and recyclability: the recent proposals put forward by the European Commission mandate that industrially compostable packaging will only be allowed for tea bags, filter coffee pods and pads, fruit and vegetable stickers, and very light plastic bags. It also foresees that other packaging, including bio-based biodegradable packaging, has to allow for material recycling without affecting the recyclability of other waste streams.

Moreover, *EU Directive 2019/904 on the reduction of the impact of certain plastic products on the environment,* the so-called Directive on Single-Use Plastics (SUP), which was developed to

[5] Proposal for a Regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC

tackle plastic pollution and marine litter, specifically includes bio-based and biodegradable plastics. The inclusion was made due to the lack of widely agreed technical standards which are available to certify that a specific plastic product will properly biodegradable in the marine environment over a short timeframe and without causing harm to the environment. So, some single-use plastic products such as cutlery, even if made in biodegradable and compostable materials, will be banned (*Deliverable 5.7*).

As a side note, the communication emphasises that biobased and biodegradable plastics should not be considered as a solution for inappropriate waste management or littering.

Bio-based plastic content: technical and political aspects
There is currently no obligation for producers to disclose the exact amount of bio-based materials in their product. Producers can, of course, provide this information to consumers on a volunteer basis. However, it is also important to ensure that bio-based content is measured [5] and accurately communicated in order to avoid greenwashing and misleading consumers.

Biodegradation vs durability
Durability is one of the main characteristics of conventional plastic; good shelf-life and durability are necessary features to guarantee the quality of the final product. However, on the other hand, if composting or littering ("the worst case") represent the end-of-life scenario, the degradation undergone by the material during its life can be an advantage in its disposal, ensuring easier biodegradation.

Therefore, one of the technological challenges of bio-based and biodegradable plastics deployment is to find the right balance between material performance and its sustainability in terms of environmental impact and waste management.

Lack of harmonised waste management system
The confusion about the disposal of bio-based and biodegradable plastics is also due to the different waste management infrastructures implemented across the European Union.

For example, in Denmark, Norway, Germany and the UK, anaerobic digestion processes are extensively used to treat food waste, often, without a secondary composting stage, while in other countries (i.e., in Italy) the industrial composting infrastructures are more widespread and, usually, the process duration is longer (*Deliverable 5.7*).

In Denmark, many municipalities collect food waste with fossil-based plastic bags and the latter are sorted out in the pre-treatment of the anaerobic digestion plants (*Deliverable 5.7*) and in UK composting facilities refuse to accept PLA in food and garden waste [3], while in Italy, biodegradable and compostable bags are used to collect food waste. However, technicians of an Italian waste management company[6] said that, so far, systems are not able to separate the compostable plastic part from the non-compostable one, therefore the resulting mix ends up in large part disposed of to landfill or incineration.

The possibility of collecting, sorting and recycling waste also depends on the type of end-products: packaging is covered by extended producer responsibility (EPR) scheme, while toys

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[6] Stakeholder interview by TICASS

(regardless of the material) are not covered and, often, are sent to landfill or incineration at the moment.

In a report on *Biodegradability of plastics*, Science Advice for Policy by European Academies [4], reported that an effective waste infrastructure should indicate to consumers what government and industry are taking action on. Indeed, without an efficient waste management system that supports the recycling and sorting of materials, even the most effective labelling is unlikely to be sufficient to ensure a proper waste disposal.

Unclear labelling

Bio-based and biodegradable plastics include different kind of materials and an adequate product labelling to indicate the type of material and the correct end-of-life disposal pathways is lacking (*Deliverable 5.7*). For example, according to the European recycling codes[7], the bio-based and biodegradable plastics should be marked with number 7 which indicates *miscellaneous plastic material* including harmful plastic (*Deliverable 4.3*).

Therefore, this situation does not help consumers to clearly distinguish bio-based and biodegradable materials from other ones, especially packaging and dishware, and can generate confusion about the performance of different plastics in relation to end-of-life disposal. As a result, bio-based and biodegradable materials can be mixed with conventional plastics, contaminating the recycling process [3] or, even sent to landfill.

In addition, the different waste management systems among the European countries (see the previous critical issue) could generate consumer confusion. In fact, even in regions where industrial composting plants do not accept compostable plastics, compostable products may show the labelling of "OK compost INDUSTRIAL"[8], wrongly convincing people to throw them away with the organic waste.

Insufficient implementation of recycling systems

Various studies have shown that mechanical recycling is the best alternative for bio-based and biodegradable materials such as PLA, allowing the possibility of reusing materials. Mechanical recycling could also be applied to multiuse products such as cutlery or fishing crates, as well as durable products such as toys, rigid packaging and fishing bait.

However, at the moment, this kind of recycling is rarely used (*Deliverable 4.3*). Bio-based and biodegradable plastics cannot be recycled in the conventional plastic recycling plant as the recycling process is very different [3] and some of these types of plastic are sensitive to structural and thermal degradation with performance decreasing of final recycled product.

Moreover, the implementation of collection, sorting and recycling system for bio-based and biodegradable plastics is still economically unfeasible to date due to their small market size (*Deliverable 4.3*): quantities are not yet significant enough to justify ad hoc separation and recycling chain.

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[7] Recycling codes are used to identify the materials out of which the item is made, to facilitate easier recycling process.

[8] The label OK compost INDUSTRIAL guarantees that products are biodegradable in an industrial composting. This certification is given by TUV Austria, a certification body authorized by European Bioplastics (www.tuv-at.be)

Still uncertainty about the biodegradation into natural environment

The biodegradation of a material depends both on the type of material and on environmental conditions, thus bio-based and biodegradable plastic products do not always decompose and disappear quickly in the environment (*Deliverable 5.7 and Deliverable 4.3*). For example, PLA degrades fast at high temperature (around 60°C), but very slowly under other environmental condition such as those found in soil or sea; so, it should be treated via an industrial composting plant. Furthermore, additives are often added to bio-based and biodegradable plastic products, sometimes causing lower biodegradability.

A lack of international agreement and harmonization on the biodegradation standard application still exists and the uncertainty about the actual biodegradation of bio-based and biodegradable plastics in soil or sea or freshwater - when they have to be left in the open environment as mulch films and geomaterial membrane - could hold back the diffusion of these materials.

2.2.2 Classification of Critical issues based on target applications

In the critical issues identification process, the following applications (studied within the project) have been considered:

- Cutlery - C
- Agricultural mulch films – AMF
- Aquatic applications
    - Fish crates - FC
    - Fishing baits - FB
    - Marine geomaterials (same material of mulch film) – MG
- Packaging
    - Soft packaging -SP
    - Rigid packaging (same material of fish crates) - RP
- Toys (same material of fishing baits) - T

In addition to the application, material composition and end-of-life scenario defined for each application within the project (Table 3) have been taken into account.

Table 3: Material and end-of-life scenario defined for each application within the project.

Target Application	Material	Use	End-of-life scenario
Cutlery	PLA-based compound	Multiple use cutlery	Primary – long usage phase; secondary – recycling by producer themselves; tertiary – composting
Agricultural Mulch Films	PLA-based compound	Mulch film to cover fields during growth phase (agriculture application)	In-situ degradation
Marine Geomaterial	PLA-based compound	Thick film or sheets that stabilize ground before plants have grown sufficiently	In-situ degradation

Rigid packaging	PLA-based compound	Packaging suitable for cosmetics and food	Primary – post-industrial and post-consumer recycling; secondary – industrial composting
Fish Crates	PLA-based compound	Rigid or foamed crates to transport or store fish – multiple use	Primary – post-industrial and post-consumer recycling; secondary – industrial composting
Soft packaging	PBS-based compound	Food packaging such as yoghurt pot	Primary – industrial composting; secondary – mechanical recycling for post-industrial refuse
Toys	PHBV-based compound	Durable products (e.g., beach toys)	Primary – durable products that can degrade in environment if lost; secondary – recycling by producer (private collection)
Fishing Bait	PHBV-based compound	Baits and lures for angling	Primary – durable products that can degrade in environment if lost; secondary – recycling by producer (private collection)

The correlation between the identified 10 critical issues and the target applications are reported in Table 4.

Table 4 Correlation between the identified 10 critical issues and the specific applications.

Critical Issues	C	AMF	MG	RP	FC	SP	T	FB
Feedstocks	x	x	x	x	x	x	x	x
High price	x	x	x	x	x	x	x	x
Environmental impacts of production and disposal	x	x	x	x	x	x	x	x
Recyclability vs biodegradability according to European policy framework	x	x	x	x	x	x	x	x
Bio-based plastic content: technical and political aspects	x	x	x	x	x	x	x	x
Biodegradability vs durability	x	x	x	x	x	x	x	x
Lack of harmonised waste management system	x			x	x	x	x	x
Unclear labelling	x			x		x		
Insufficient implementation of recycling system	x			x	x		x	x
Still uncertainty about the biodegradation into natural environment		x	x				x	x

2.3 SWOT analysis

To have a clear picture of information and data related to the environment analysis, a variety of tools and techniques can be used: SWOT, PESTEL, porter five forces, etc.

For Task 5.3 implementation, the tool chosen is SWOT analysis because it is a proper tool to organize and summarize such kind of information: what are internal, what are external, what are good and what are bad. Some information and results have already obtained in other tasks (Task 5.2) and WPs (WP7) where tools such as PESTEL analysis and porter five forces analysis have been applied.

The identified critical issues (paragraph 2.2) are considered in the SWOT analysis implementation.

The SWOT analysis related to the development of the whole bio-plastics system in a circular economy perspective is reported in Table 5.

Table 5 SWOT analysis related to the development of the whole bio-plastics system in a circular economy perspective.

SWOT ANALYSIS		
	STRENGHTS	**WEAKNESSES**
INTERNAL	• Reduction of fossil resources use. • Potential biodegradability and compostability. • Potential less harmful than conventional plastics regarding the micro-plastic impact on marine environment, food chain and human health.	• Feedstocks: competition for agricultural land with food products. • High price of bio-based materials and products. • Low input volume of bio-based plastic waste for mechanical recyclability. • Still technical issues to increase the recyclability and durability of bio-based plastic products. • Still use of no bio-based additives in the bio-based plastic products.
	OPPORTUNITIES	**THREATS**
EXTERNAL	• Development of European strategy for circular economy, environmental sustainability and against plastic pollution. • Development of EU policy framework on bio-based, biodegradable and compostable plastics. • Bio-based and biodegradable plastics market growth. • Increasing of environmental-friendly consumers. • Possibility of use by-products, agricultural and food waste as feedstocks for bio-based and biodegradable plastic material production.	• Unclear labelling and consumer confusion. • No harmonization of biodegradation standards. • No waste management harmonization across European countries. • No obligation to disclose the exact amount of bio-based plastic material in the products. • More focus of EU on recycled plastic than on biodegradable and compostable plastic. • Raw material price fluctuation.

3 Identification, evaluation, and selection of replicable strategies

The replicable strategies to address the circular innovation of the whole bio-plastics system have been selected through a continuous and circular strategy development process, in which preliminary results have been used as learning phase.

Involving various stakeholders in the process is crucial to ensuring practicality, relevance, and broad acceptance of the selected strategies.

3.1 Stakeholder consultation through interviews

Within Task 5.2, in which TICASS has been involved, stakeholder consultation through interviews and a focus group have been conducted. The main goals of these consultations were to assess the suitability of biodegradable and compostable alternatives in specific applications and to identify policy gaps and opportunities for their development.

The stakeholders involved were mainly producers, European association members, waste managers, researchers and policy makers (for full details see: D5.2 – *Technical Report: biodegradable and compostable solutions supporting policymaking in research, innovation and technology with focus on the EU Plastic Strategy*)

The following key points came to light as significant for Task 5.3:

- Bio-based and compostable plastics are suitable for organic waste bags and all applications in contact with food such as shoppers, fruit and vegetable bags, tea and coffee bags: especially where their end-of-life treatment with organic waste is easier at logistical and environmental levels. Also, compostable cutlery can be collected with food waste for organic recycling.
- Other good applications for bio-based and biodegradable plastic materials are those applications related to agriculture such as mulch films.
- Bio-based and compostable plastics are not suitable for applications that are not good for organic recycling: rigid packaging that remains clean after use (such as water bottles) or that is not used for food (such as detergents): for these applications, bio-based plastics, even if not biodegradable, could be suitable.
- A good connection between compostable plastic uses and organic waste collection and treatment is very important: organic waste treatment infrastructures should be able to treat compostable plastics.
- Using conventional plastic for organic waste collection can cause problems in the anaerobic digestion and composting processes and can generate permanent microplastics.
- Increasing the availability of infrastructures for all recycling options, including organic, mechanical, and chemical recycling, is crucial to achieving recycling targets and ensuring a sustainable future for recycling at scale. Different countries have different waste management systems: challenging for producers in developing materials to be exported in various countries.

- Clear labelling: consumers need to be informed on the proper disposal of products, either if they are bio-based and biodegradable plastics, conventional plastics, paper packaging, etc.
- At European level, the regulations often treat bio-based and biodegradable plastics in the same way as conventional plastics.
- European Plastic Strategy focuses on recyclable/reusable plastic.

These results have been taken into account for the organization of the Innovation workshop (see section 3.2).

3.2 Innovation workshop: "Replicable strategies for bio-plastics deployment."

An innovation workshop, based on the Design Thinking methodology, was organized in Genoa during Spring 2023, with the aim of identifying the best strategies based on a circular approach to overcome the defined critical issues which could hinder the valorisation, development and diffusion of biodegradable and bio-based plastics, with a focus on the local context.

Based on the results obtained by the previous phases of the strategy development process, it was decided that two parallel sessions would be undertaken to address the challenges of single-use and multiple-use materials in bio-plastics deployment, focusing on single-use soft and rigid food packaging and multiple-use cutlery.

A targeted range of local stakeholder has been involved in order to join different experiences, skills and needs: municipality, producers, marketing experts and waste management bodies (Table 6).

Table 6. List of participants at the Innovation Workshop

Organization	Sector	Number of participants
AMIU	Municipal waste management	2
Municipality of Genoa	Municipality	2
Gruppo Iren	Waste management – organic recycling	1
Relife Plastic Packaging	Plastics recycling	1
BTA – Biotechnical recycling	Organic recycling	2
Istituto Italiano di Tecnologia	Research on bio-plastic material production	1
Amico Bicchiere	Multiple-use cutlery and glass supply	1
TICASS	Partner of BIO-PLASTICS EUROPE project	3

The workshop was structured into 3 phases:

Phase 1: 2-hour virtual meeting, held on the 27th March 2023, to introduce "Design Thinking" methodology to the participants with the aim of:

- becoming familiar with the key steps of the design thinking process, such as problem framing, ideation, prototyping, and testing;
- introducing tools and techniques used in Design Thinking;
- showing clear goals and objectives of the workshop, setting expectations for the subsequent phases and introducing the challenges to be addressed;
- defining the "Design Thinking" mindset.

Phase 2: In-Person Meeting, held on the 14th April 2023, to Discuss Strategies based on the defined 10 Critical Issues related to bio-plastics deployment (Chapter 2).

Potential solutions and strategies were explored utilizing design thinking techniques for ideation, including:

- the fishbone diagram, which allows participants to identify and understand challenges and opportunities,
- the empathy map, which allows participants to gain a deeper understanding of the needs, desires, and pain points of different stakeholders involved in bio-plastics deployment,
- the "How Might We" technique, a brainstorming method to ideate creative solutions while keeping teams focused on the right problems to solve,
- GPS Maps which helps participants focus on certain priorities and to select ideas coming from brainstorming activities.

The proposed strategies were detailed and then discussed, considering their feasibility, sustainability, scalability, and potential impact with generation of the "How, Now, Wow" matrix which forced participants to weigh each idea on 2 parameters: originality and feasibility.

Phase 3: Conclusive Virtual Meeting, held on the 5th May 2023, for the presentation and sharing of the refined strategies generated during the in-person meeting.

In addition to these phase-specific outcomes, it's important to note that the workshop provided the participants with an opportunity to share their expertise, exchange experiences and to promote networking and collaboration among stakeholders.

The majority of the opportunities, barriers and facilitators raised during the workshop were found to be common across both challenges: single-use and multiple-use materials (Table 7).

Table 7 Opportunities, barriers and facilitators raised during the Innovation Workshop

OPPORTUNITIES	FACILITATORS	BARRIERS
Identification of end-to-end process throughout the entire value chain of bio-plastics (design, production, utilization and disposal) that is: • economic and environmental sustainability.	• Research aimed at **identifying target applications** in which bio-plastics could represent an added value in terms of economic and environmental sustainability. • **Collaboration among stakeholders** involving municipality,	• **Lack of awareness** and familiarity with bio-plastics may lead to **resistance to change from consumers** and to **confusion** about proper disposal methods. • **No confidence** in the waste management

• an incentive system for both citizens and companies. These systems shall **support people in the choice of a product and in the correct disposal**, as well as producing value through incentives for bio-plastic production/utilization and **growing demand for sustainable and eco-friendly solutions.**	bio-plastics manufacturers, marketing experts, and waste management bodies to facilitate the sharing of knowledge, resources, and dialogue. • Governments providing **incentives**, grants, and funding for research, development, commercialization and disposal of bio-plastics can drive innovation and adoption. • Development of **clear guidelines and standards** for bio-plastic, including information about products shelf-life and their end-of-life. • Increase of **consumer awareness** and **producer responsibility** educating the public in sustainable practices and **adopting of the good practices** and sustainability goals at school, institutions and workplaces. • **Comprehensive life cycle assessments and sustainability analysis** throughout the entire value chain of bio-plastics by **collecting and sharing data** about production, disposal management, end-of-waste plants and processes.	systems: **misleading greenwashing claims.** • **Lack of competitive business model**: high production costs and limited market demand. • **Mismatch between normative and the real-world** disposal technologies and infrastructures. • **Lack of infrastructures** for bio-plastic waste management. • **Lack of clarity**, simplicity and transparency of the normative. • **Lack of legislative harmonization** at national and European level, that produce confusion for manufacturers, consumers, and waste management systems: diverse standards and labels. • **Confusion** and misinformation about bio-plastic definitions and properties.

Based on the table above, here are the defined priorities for supporting the deployment of the whole bio-plastic system:

- **Research and Development for Target Applications**: Prioritize research aimed at identifying target applications where bio-plastics can offer economic and environmental sustainability benefits. The research process shall include also evaluation of production phase (i.e. costs, environmental impacts of the process) and toxicity assessments of the final product towards environments and on human health. This will help showcase the added value of bio-plastics and encourage their adoption in specific sectors.
- **Technological advancements** of the whole bio-plastic systems including developments of **single-material products** and investing in **waste management technologies** (as bio-plastic recycling and composting), to overcome the lack of infrastructure for bio-plastic waste management and create efficient disposal systems. Establishing a **technical working group** of experts in waste management would be beneficial for the development of facilities and systems to handle bio-plastic waste effectively. The group's main

objective would be to develop strategies and guidelines for the establishment of necessary infrastructure, including collection, sorting, recycling, and composting facilities, starting from identification of challenges and available data exchange (i.e. volume of waste actually biodegraded/recycled and volume of waste that wind up in a landfill). For multiple-use products it is also fundamental to invest in designs that allow to **repair** rather than encouraging dispose and replace.

- **Government Support and Incentives**: Governments and regulatory bodies shall implement policies that encourage the use of good practices such as **taxes** to those not complying with the regulations and **incentives** for research, development, commercialization and disposal of bio-plastics, driving their innovation and adoption.
- **Normative Clarity and Harmonization**: Prioritize the development of **clear guidelines and standards** for bio-plastics, including information about product shelf-life and end-of-life considerations. These guidelines should be easily accessible and transparent (i.e. by using QR code or NFC) to facilitate proper use, disposal, and waste management practices. Regulatory bodies shall promote **normative harmonization** at national and European level, that can enhance consumer confidence, support proper waste management, and foster market growth.
- **Consumer Education and Awareness**: Educating consumers about sustainable practices and proper disposal methods should be a priority, encouraging **responsible consumer behaviour**. Consumer awareness could be reached by implementing **training activities at various levels**, as schools, universities and companies and by clear and effective communication and dissemination. Training and development are important aspects also for **corporate cultures centred around sustainability principles**, promoting producer responsibility and increasing consumer awareness about bio-plastics through the adoption of "good practices" in the workplace and outside.

3.3 TOWS matrix

The final definition of replicable strategies has been made using the TOWS (Threats, Opportunities, Weaknesses, Strengths) matrix. It is useful for creating strategic options based on the findings in the SWOT analysis and it allows to capitalize opportunities, leverage strengths, counter threats and smooth weaknesses:

- SO strategies: using strengths to take advantage of opportunities;
- ST strategies: using strengths to avoid threats;
- WO strategies: overcome weaknesses to take advantage of opportunities;
- WT strategies: minimize weaknesses and avoid threats.

In the strategy development process carried out by Task 5.3, the TOWS matrix (Table 8) has been elaborated, taking into account the stakeholder consultation results.

Table 8 TOWS Matrix

TOWS MATRIX		
	STRENGTHS	**WEAKNESSES**
OPPORTUNITIES	*SO strategies* • Implementing policies that encourage the use of bio-plastic materials for suitable applications, reducing fossil resources and environmental impacts. • Establishing of technical working groups involving municipality, producers, marketing experts, and waste managers to facilitate the sharing of knowledge, resources, and dialogue.	*WO strategies* • Promoting normative harmonization at national and European level, that can enhance consumer confidence, support proper waste management, and foster market growth. • Using simple tools to make clearer the communication about bio-plastic materials and their end-of-life scenarios.
THREATS	*ST strategies* • Prioritizing research and development of target applications to overcome technical issues and high price. • Increasing the consumer awareness also implementing training activities at various levels.	*WT strategies* • Prioritizing the development of clear guidelines and standards for bio-plastic material to avoid producer and consumer confusion. • Investing in waste management technologies (as bio-plastic recycling and composting), to overcome the lack of infrastructures for bio-plastic waste management and create efficient disposal systems.

4 Evaluation of defined strategy applicability

4.1 Case of study in the Municipality of Genoa (IT)

In this section, we will evaluate the applicability of the selected replicable strategies for promoting the adoption of bio-based and biodegradable plastic products in the Municipality of Genoa. The target area for the applicability assessment has been identified as the public events/exhibitions domain. This domain encompasses a range of public gatherings, including cultural events, exhibitions, fairs, and festivals, which attract diverse audiences and provide opportunities for engaging citizens on sustainability practices. The focus of this evaluation is to address critical issues hindering the widespread adoption of sustainable plastic alternatives.

Recognizing that social aspects, consumers and citizens play a crucial role, therefore it is essential to engage and involve them in the evaluation process. For this purpose, " The Ocean

Race Genova -The Grand Finale 2022-23" was chosen as the target area for this evaluation, offering an opportunity to effectively involve citizens and ensure replicability.

“The Ocean Race Genova -The Grand Finale 2022-23" is a renowned international sailing event that promotes sustainability and environmental awareness.

The evaluation focused on the waste management in the food area and the end-of-life of installations, addressing **regulatory aspects, waste management technologies**, **consumer education and awareness.**

1) **Government support and regulatory aspects**: in line with the event's principles, a **technical working group** of experts in waste management was established for drawing up a comprehensive Sustainability Action Plan and Sustainability Policy, that incorporate guidelines from EU directives. The working group worked in closely collaboration with Municipality of Genoa.
2) **Waste management and corresponding technologies in the food area:** to improve waste management in the food area, recycling bins was provided, and staff was engaged to assist users and provide guidance on proper waste disposal, assuring the complying with the guidelines established by the Municipality of Genoa. In this way, it is possible to reach a large audience, **educating consumers** about sustainable practices and proper disposal methods. However, the presence of multiple types of materials used for cutlery, bottles, and other items posed a challenge, leading to confusion among participants regarding proper disposal methods and recycling options. To overcome this challenge, event organizers should manage all materials used in the food area for tableware, bottles, and other items, availing of two potential strategies:
   a) **Standardizing Materials and implementing waste management infrastructures**: the implementation of consistent and recyclable materials will simplify waste management for participants and improve recycling rates. To effectively manage bioplastics waste, developing a separate collection system is crucial: by separating bioplastics at the source, the potential for contamination and improper disposal practices can be minimized, enabling more efficient recycling or composting. **Recycling facilities** for bio-plastics can utilize technologies specifically designed to process these materials, ensuring optimal recovery of valuable resources. **Composting facilities**, on the other hand, should have the capacity to efficiently decompose bioplastics through controlled composting processes, creating valuable organic matter.
   b) **Multiple-Use Cutlery and Rental Services:** promoting the use of multiple-use cutlery made from sustainable materials, such as bio-plastics, is an effective strategy to reduce plastic waste during " The Ocean Race Genova -The Grand Finale 2022-23". By providing participants with reusable cutlery, the reliance on single-use plastics can be significantly reduced. Implementing rental services for reusable cutlery offers a convenient and eco-friendly option. To set up rental services, the technical working group should collaborate with specialized rental companies to ensure an adequate supply of reusable cutlery sets. A dedicated area or booth should be established at convenient locations within the event premises. This area should be clearly marked and staffed with knowledgeable personnel to assist users, answer their questions, and provide guidance on proper handling and hygiene practices. Participants can easily rent and return the cutlery sets, which can include the cost of withdrawal and cleaning, making it economically convenient for them.

3) **End-of-Life of Installations and waste management infrastructures:** The "Ocean Race Genova -The Grand Finale 2022-23" working group include a zero-waste manager, which is involved in the activities to address the end-of-life of installations. In line with the **sustainability principles and circular economy strategies,** the **repurposing and recycling** of event banners was evaluated. In particular, a portion of the banner material can be used to produce reusable bags, reducing the demand for single-use plastic bags. The remaining banner material should be collected separately and sent for recycling. This approach ensures the maximum utilization of resources and minimizes waste.

In conclusion, " The Ocean Race Genova -The Grand Finale 2022-23" in the Municipality of Genoa presented an opportunity to leverage a renowned international and sustainable event to drive the valorisation and adoption of bio-plastics. By implementing recommendations such as standardizing tableware materials, promoting multiple-use cutlery, and repurposing/recycling event banners, the municipality was able to enhance its sustainability practices and contribute to a circular economy. For this purpose, it is suggested that the working group should include other key stakeholders such as producers of bio-based plastics, marketing experts and rental services for reusable products.

5 Exploitation of the defined strategies

In the view of ensuring that the selected strategies can be applied and replicated, the results will be made available for the project exploitation phase.

One of the main means of exploitation delivery will be Task 5.4, providing "policy briefs" in a form that allows for efficient feedback into policymaking in research, innovation and technology, in particular in the EU Plastic Strategy.

Furthermore, this Deliverable will be shared with the participants to the Innovation Workshop (paragraph 3.2) and "The Ocean Race Genova -The Grand Finale 2022-23" organizers (chapter 4) in order to spread the results of the strategy development process and encourage the improvement and implementation of the replicable strategies in other events and contexts.

6 Conclusions

This Deliverable has reported the identification, evaluation, and selection of strategies for circular innovation of the whole bio-plastics system.

In the strategy development process, the importance of stakeholder engagement emerged, especially the involvement of people with different backgrounds and experiences, to allow for situations to be seen from different points of view and to more easily find useful strategies to overcome critical issues and capitalize opportunities.

To support the deployment of bio-plastic materials, the following main key points have emerged.

- Clear regulations and standards for bio-plastic materials at European and national level are a priority for harmonizing the bio-plastic system, helping producers to select the right investments and the most suitable market, and in supporting proper waste management.

- Clear and user-friendly communication including information about product shelf-life and end-of-life considerations is needed to enhance consumer confidence and facilitate the proper use and disposal of bio-plastic materials.
- Further research on the whole bio-plastic system (from production to disposal) should be encouraged to overcome technical and economic issues still in place.
- Technical working groups that include people from different sectors of the entire value chain are a good opportunity to find proper and concrete strategies and to overcome critical issues and threats.
- Dissemination of the selected strategies will be encouraged on several occasions to support their replicability.

7 References

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