SCIENCE FOR POLICY BRIEF – Bio-based products

Bio-based plastics in a sustainable and circular bioeconomy

2026

HIGHLIGHTS

- In the context of growing global demand of plastic products, bio-based plastics are generally included in the strategies to mitigate associated climate change and environmental impacts.
- Bio-based plastics include a broad category of polymers that can have a fossil-based counterpart or not, be biodegradable or not. In this brief, they are classified based on the step in the production process where fossil feedstocks are replaced by biomass.
- As of 2025, bio-based and biodegradable plastics accounted globally for roughly 0.5 % of the total plastics production. Global annual production capacity is around 2.3 Mt, and based on announced capacity expansions, it is projected to grow to about 4.7 Mt by 2030.
- The scale up of the sector is challenged by several issues, mainly related to competitiveness, sustainable feedstock sourcing and use, end of life management, assessment of environmental impacts, innovation aspects (e.g. technical development), and consumers' attitudes.
- The bio-based plastic industry could potentially grow in the EU, relying on domestic feedstock. Such development is expected not only to bring socio-economic advantages in terms of job opportunities and strategic autonomy, but also to help improve recyclability and end-of-life management.
- Replacing fossil feedstocks generally lowers the greenhouse gas emissions over the product's whole life cycle, while for the other environmental impact categories trade-offs may also occur.

Policy context and scope

Many countries share the goal of reducing their dependency on fossil-based plastics and reducing plastic pollution. Despite this alignment in principles, **specific regulatory approaches vary**.

The European Union puts in place strategies, directives and regulations to ensure that plastics are produced, used and disposed of in an environmentally responsible manner. The European Green Deal (COM/2019/640) targets climate neutrality by 2050 and promotes sustainable production processes across all sectors. Building on this objective, the Circular Economy Action Plan (COM/2020/98) calls for enhanced product design, waste prevention, and clearer rules regarding sustainable materials. The EU Bioeconomy Strategy (COM/2025/960) aims to advance the use of renewable biological resources within ecological boundaries, to reduce fossil fuel dependency and stimulate innovation in bio-based products, including plastics. The European Strategy for Plastics in a Circular Economy (COM/2018/28) sets ambitious recycling targets and encourages sustainable product design, explicitly recognising the potential of bio-based plastics. The EU Policy Framework for Bio-based, Biodegradable and Compostable Plastics (COM/2022/682) offers further guidance to ensure that these materials deliver genuine environmental benefits. Complementary measures include the Single-Use Plastics Directive (SUP, EU/2019/904) and the Packaging and Packaging Waste Regulation (PPWR, EU/2025/40) which establish rules to reduce waste and promote recyclability and compostability. On the other hand, the SUP Directive applies provisions which do not exempt biodegradable plastics and the PPWR sets recyclability requirements which also apply to new bio-based plastics, hampering their access to the market.

Non-EU countries tend to rely on broader legislation or national action plans with varying degrees of central or regional enforcement. Some, such as Japan and India, offer explicit production incentives and targets, while others like the US and Canada balance voluntary programs and partial mandates with emerging federal frameworks that still allow for subnational divergences.

Definitions and classifications

Plastics are thermoplastic polymers that are shapable by flow at some stage of their processing into finished products[1].

Bio-based plastics are wholly or partly derived from biomass feedstock, which is renewable when it can be continually replenished (EN 16575).

Biodegradable plastics can be broken down into water, naturally occurring gas and biomass by microorganisms (bacteria or fungi). Biodegradability is a system property, resulting from the interaction between the material properties of the plastic and the environment in which it biodegrades [1].

Compostable plastics, a subclass of biodegradable plastics, degrade at composting conditions. Industrial composting conditions require high temperatures, consistent oxygen levels,specific moisture content and high microbial activity. Criteria are listed in the EN 13432 standard. Home composting occurs at lower temperatures.

Plastics can be both bio-based and biodegradable, but one does not automatically imply the other. Some fossil-based polymers are biodegradable while some bio-based ones are not (Figure 2).

Bio-based plastic types

Bio-based plastics are a versatile group of materials that can be classified in different manners. This brief classifies bio-based plastics *based on the stage of the production process where fossil feedstocks are replaced by biomass*, obtaining three main types of bio-based plastics:

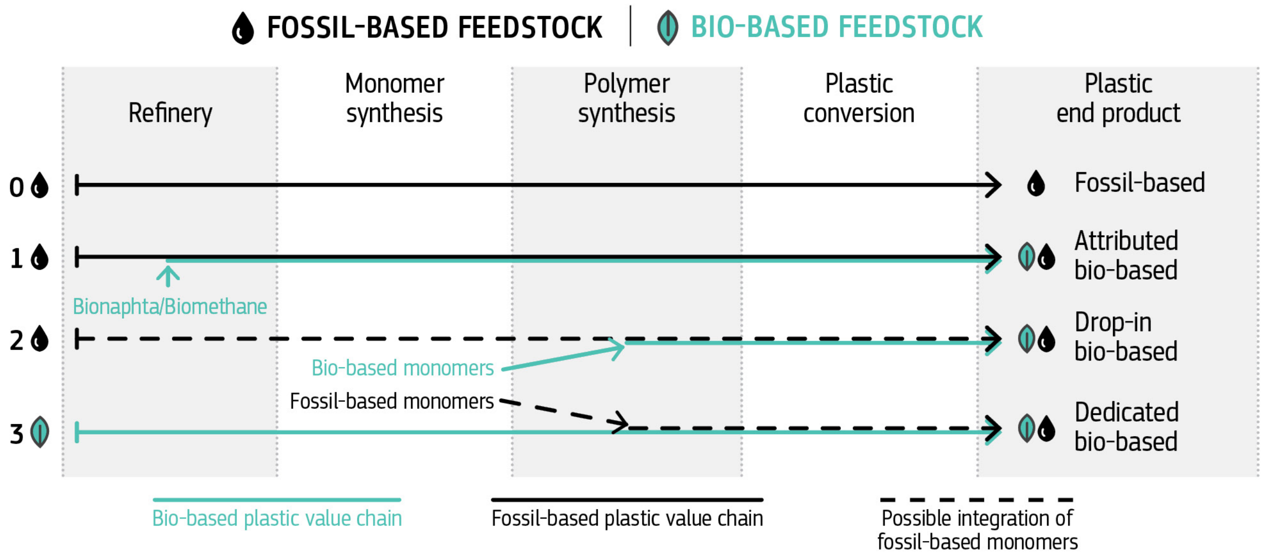
1. Attributed (or certified) bio-based plastics
2. Drop-in bio-based plastics
3. Dedicated bio-based plastics

The selection of the optimal production route is commonly based on viability, availability and type of biomass feedstock and available production assets.

In Figure 1, route 0 depicts fossil-based plastics production in four steps: i) feeding the oil refinery with fossil-based feedstock, ii) monomer synthesis, iii) polymer synthesis, iv) conversion into the fossil-based plastics end-product. The most common fossil feedstock is naphtha, extracted from crude oil or produced from natural gas.

[1] In the Single Use Plastic Directive (SUP), plastics are defined as materials consisting of a polymer that can function as the main structural component of a product, and to which additives or other substances may have been added. Unmodified natural polymers are excluded from this definition.

Figure 1 – Production routes for plastics



Source: Own elaboration

Attributed (or certified) bio-based plastics

Bio-based plastics can be produced by **co-feeding the fossil-based route with biomass-derived feedstock** (called intermediates), in the refinery phase, to obtain the so-called attributed (or certified) bio-based plastics (Figure 1, route 1). In this case, the fraction of biogenic carbon on the total carbon content is not measured but attributed to a specific product by using a mass balance method. The share of bio-based feedstock can vary, and it is not traceable. Typical bio-based intermediates include biomethane, biomethanol, and bionaphtha. In principle, all fossil-based plastics can be replaced by attributed (or certified) bio-based plastics, but their market penetration is currently low. Bionaphtha produced from (waste) vegetable oils and tall oil is already co-fed in current naphtha crackers to produce bio-attributed (or certified) bio-based plastics.

Drop-in bio-based plastics

Route 2 of Figure 1 shows that polymer **building blocks** (called monomers) that are identical to fossil-based building blocks can be **produced from biomass,** resulting into so-called drop-in bio-based plastics, with a measurable bio-based carbon content. Combinations with fossil-based building blocks result in partly bio-based plastics. Well-known examples include:

- 100 % bio-based PE (polyethylene) made by producing bioethanol from sugar-rich biomass and converting it into ethylene and PE.
- 20 % bio-based PET (polyethylene terephthalate), made of bio-based MEG (mono-ethylene glycol).
- Partly bio-based PTT (polytrimethylene terephthalate), made with bio-MPG (bio-based mono-propylene glycol), derived from wood or glycerol, a by-product of biodiesel production.

Drop-in bio-based plastics (e.g., bioPE, bioPET) can seamlessly integrate into existing waste management infrastructures without requiring modifications to processing or recycling. These materials are chemically identical to fossil-based counterparts, enabling direct substitution and reducing barriers to adoption. On the other hand, they have no functional advantages and their higher price limits market acceptance.

Dedicated bio-based plastics

Route 3 of Figure 1, indicates the production route of “dedicated” bio-based plastics, starting at biorefinery sites. This type of bio-based plastics is developed to optimally **convert biomass into plastic products**, and to decouple from fossil feedstock and conventional plastic production systems. They can be produced:

a. through (modification of) natural polymers;
b. by producing bio-based building blocks;
c. directly by micro-organisms.

It can be noted that the development of plastics started in the 19th century with **modified natural polymers** like cellulose acetate (CA) and celluloid. Nowadays these plastics are produced from dissolving pulp and are used in cigarette filters, textiles, spectacle frames, screwdriver handles, displays and protective films [2]. TPS (Thermoplastic starch) is a more recently developed plastic, which finds application in biodegradable mulching films, carrier bags and organic waste collection bags. Typically, these products contain other bio-based or fossil-based biodegradable plastics to enhance properties.

Bio-based plastics produced from **bio-based building blocks** are a wide group, including various nylons and polyesters.
Nylons are typically used in high-end applications (e.g., oil & gas industry, automotive, electronics, medical devices) and can be used as a barrier material in packaging. Nylon 11 (Rilsan 11) is an early example: it was developed in the 1950's from castor oil.
Among the "new" bio-based polyesters, PLA (polylactic acid) is the most important at commercial scale. Its building block, lactic acid, can be produced via anaerobic fermentation of sugar and starch [3]. PLA can be used in packaging (coffee capsules, thermoformed trays, cups), agriculture (plant pots, binding yarn) and in durable applications (automotive parts, computer housings, toys). It biodegrades in industrial composting facilities and does not accumulate in the environment.
Other bio-based polyesters are bio-based PBS (polybutylene succinate), and PBSA (Polybutylene succinate adipate), that has a higher biodegradation rate. The high toughness and resemblance with HDPE (high-density polyethylene) and PP (Polypropylene) as well as the excellent processing behaviour in injection moulding applications are the main assets of PBS. PEF (Polyethylene furanoate) is a more recent example. Although PEF resembles PET, it can be produced more efficiently from biomass, using sugars extracted from wheat or wood. Moreover, it has better barrier properties, making it suitable for mono-material barrier packaging solutions.

Some bio-based plastics can be produced **directly by micro-organisms**. Well-known examples are PHAs (polyhydroxy alkanoates), a family of bio-based polyesters. PHAs are potentially biodegradable in all natural environments and can be made of primary (sugars, vegetable oils, methane) or secondary feedstocks, to reduce both costs and environmental footprint. PHAs are used in various mono-material products like reusable coffee cups and coffee capsules. They are commonly blended with other biodegradable plastics to improve their properties of these biodegradable plastics. Paper coatings, fibres and non-wovens are under development. The development of PHAs requires upscaling production and cost reductions [4].

Dedicated bio-based plastics have distinct chemical structures and compatibility issues with conventional recycling streams. Clear labelling and standardised protocols are critical for their successful integration in the existing recycling infrastructure. Sufficient volumes make recycling practices viable.

In conclusion, every plastic type described above has different characteristics (Table 1), which are highly dependent not only upon the production route, but also on the type of biomass feedstock it is made of. Figure 2 classifies the types of bio-based plastics looking at typical bio-based carbon content and biodegradability.

Table 1 - Characteristics of conventional fossil and bio-based plastics, based on qualitative assessments

	Fossil-based	Attributed (or certified) bio-based	Drop-in bio-based	Dedicated bio-based
Use of waste biomass feedstocks	no	**yes**	**yes**	**yes**
Efficient biomass use	no	*	No	**yes**
Green House Gas (GHG) reduction	no	**yes**	**yes**	**yes**
New properties (e.g. biodegradability)	**	**	**	**yes**
Versatile production	**yes**	**yes**	No	no
Enable fossil phase out	no	no	**yes**	**yes**
Fossil-like performances, fast market access	**yes**	**yes**	**yes**	no
Fit in current recycling system	**yes**	**yes**	**yes**	no***
Logistic challenges	no	**yes**	**yes**	**yes**
High costs	no	**yes**	**yes**	**yes**
Energy intensive, high env. impact process	**yes**	**yes**	no	no
Need of new facilities	no	**yes********	**yes**	**yes**

Source: own elaboration, based on qualitative assessment by authors

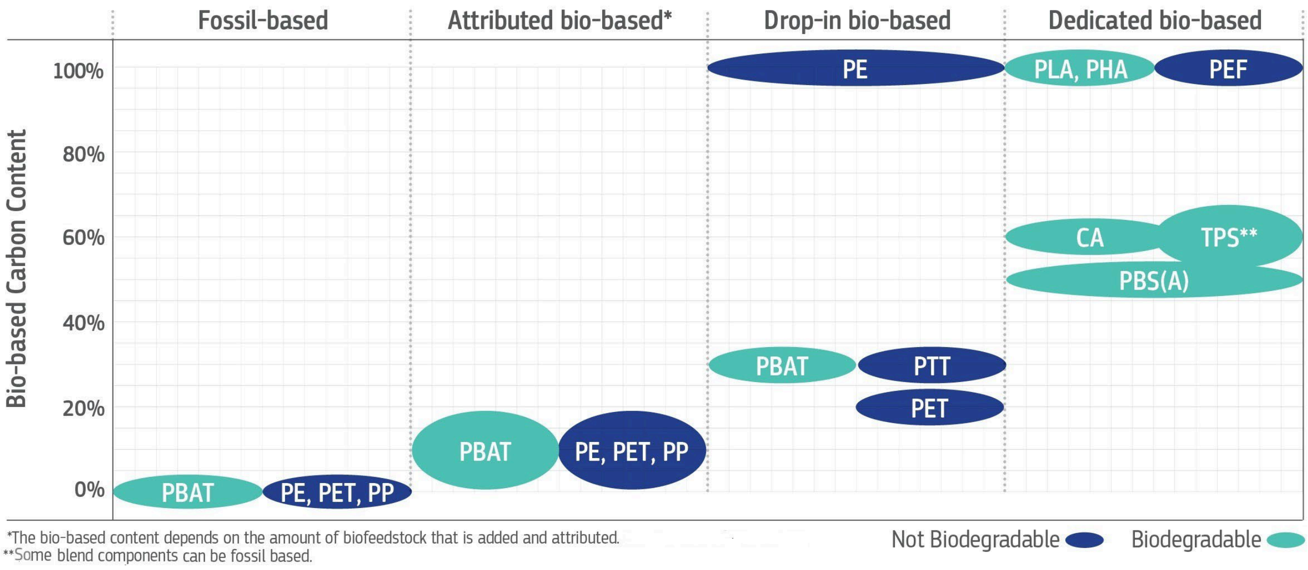
*Depending on type of biomass added. For example, bionaphtha from waste vegetable oils can be efficient, wood to bionaphtha is very inefficient.

**Assessment depends on the case. For example, PTT has better performance than PET in carpets and PEF has better barrier properties than PET.

***Challenging due to low volumes.

****Only for pre/post treatment of inputs, but changes in current installations required in the long term, to pursue electrification objectives

Figure 2 – Bio-based carbon content, biodegradability and categories



Source: own elaboration

The bio-based plastics market

At present, (conventional) plastics are widely used in numerous markets. In fact, they are cheap, versatile, easily shapable, light, durable, flexible, transparent and have high relative strength. Although most fossil resources are used for energy and fuels, the petrochemical industry consumes 10 % fossil carbon as feedstock and additionally 7 % to fuel the chemical processes [5]. Polymers account for 90 % of the output of the petrochemical industry. Virgin fossil-based plastics are highly competitive. Most are used in **packaging** (around 40 %), while about 60 % of the textile fibres (mainly fast fashion) are produced from plastics. At global level, according to PlasticsEurope[2]:

- Less than 10 % plastics are recycled, bio-based or carbon captured[3].
- Most used plastics are PE (26.2 %), PP (19 %), PVC (12.8 %) and PET (6.2 %).

Despite the focus on sustainable plastics of the last 30 years, the transition to circular and bio-based plastics is slow. As of 2025, bio-based and biodegradable plastics hold a 0.5 % share of the total annual plastics production (431 Mt). Global production capacity is estimated around 2.3 Mt, with potential to grow to about 4.7 Mt by 2030, based on announced capacity expansions[4]. The **growth is primarily driven by PLA, PHAs, and bioPE**, with biodegradable plastics showing significant growth, thanks to functional advantages in specific applications. **Packaging** stands out as the main market segment for bio-based plastics, but textile, consumer goods, and automotive also have high potential.

Recycled and bio-based plastics are generally more costly than their fossil-based counterparts (e.g. bioPE has a price premium of 15-30 %). PLA and starch blends are considered more affordable within the segment. A 2020 stakeholder survey[5] indicates limited willingness to pay high premiums for such materials.

Maturity levels vary. CA and Nylon 11 are already mature, while PLA and PBAT are reaching maturity. Other materials like PEF and some PHAs are still in early developmental stages.

The production of bio-based plastics mainly takes place in Asia, where it is also expected to grow, despite the competition with fossil-based polymers. Europe has a strong role in biodegradable fossil polyesters (e.g. PBAT) and TPS. In the 2014-2023 decade, the European rubber and bio-based plastic sector provided on average EUR 3.2 billion added value every year. It created opportunities for innovation and growth, offering about 57,000 jobs on a yearly basis, 25-30 % of which are estimated to be related to manufacturing and production of bio-based plastics [6].

[2] https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2024/
[3] Carbon capture can produce plastics from recycled carbon emissions in the plastics industry.
[4] https://www.european-bioplastics.org/market/
[5] Bio-based products: Green premium prices and consumer perception of different biomass feedstocks

Main issues at stake

Feedstock use

At present, some bio-based plastics are produced from non-food crops like wood, algae and castor oil, while the majority is produced from agricultural raw materials (sugars, starch, vegetable oils). About 50 % is produced from highly productive crops like sugar cane, wheat and corn. Existing biorefinery infrastructures can extract the functional components from these crops, ensuring the production of affordable, functional monomers. Some of the building blocks (bioethanol, bionaptha, ricinoleac acid) can be used for energy purposes, determining a relationship of both competition and synergy between biofuel and bio-based plastic producing industries, where public support can substantially make the difference. Although virgin feedstock is more commonly used, the valorisation of waste streams and residues receives a lot of attention in research but also among current bio-based plastic producers.

Table 2 - Main feedstocks[6] to produce bio-based plastics

Raw material	Feedstock	Bio-based plastic
Starch	Corn, wheat, potato, cassava	PLA, PTT, starch blends
Sugar	Sugar cane	PE, PLA
Ricinus	Castor oil	PA
Cellulose	Wood, cotton	CA
Edible oil	Palm, soy, rapeseed, sunflower	PHA

Source: own elaboration

Typically, the focus is on:

- Biomass sources not in competition with food (e.g. wood, castor oil)
- Organic residues (e.g. tall oil, whey, bagasse, straw)
- Waste streams (e.g. food waste, organic municipal waste, used vegetable oils and waste fats)

Waste and side streams are available in limited volumes, often in competition with energy uses. Scattered production locations make the logistics complex, while non-homogeneous composition requires additional processing steps, thus increasing costs and environmental impacts. Risk-based frameworks (e.g., RED III's land use and biodiversity criteria) can determine feedstock sustainability to prevent deforestation, ensure high GHG savings, and protect biodiversity. Certification schemes and due diligence along supply chains are critical to prevent unintended environmental impacts. Valorisation of feedstocks at regional scale, supportive policies (e.g., incentives for cascading use), and infrastructure for waste collection are essential. Scaling sustainable feedstock (e.g., lignocellulose) requires technological breakthroughs and focus on multiple crop uses reduces competition issues.

Regulatory measures are essential to accelerate scale-up, particularly for applications like mulching films, which are left into the environment after use. Possible measures range from setting mandatory shares of bio-based plastics into fossil-based products, to bio-based content and recycled content targets, to bans or restrictions for persistent fossil-based plastics in specific applications, and dedicated labelling, enabling better-informed consumer choices. These policies aim to ensure bio-based plastics compete fairly with conventional plastics, while meeting environmental criteria (e.g., low toxicity, biodegradability). In general, it is important to evaluate feedstock availability, sustainability, and process efficiency to minimise resource competition.

End of life

The end of life of fossil, bio-based or biodegradable plastics is subject to various claims, often not supported by evidence [1]. For this reason, studies on sorting practices for packaging waste, reporting the actual fate of persistent fossil-based and compostable plastics in organic waste treatment systems, would be valuable. The strong focus on compostability or biodegradability encourages the use of "dedicated" bio-based plastics. Examples are biowaste collection bags, mulching films and various other agricultural applications. Certification schemes are important to prevent negative effects originating from inappropriate product design.
Dedicated bio-based plastics do not fit in current plastic recycling schemes yet, and it is not viable to build parallel recycling systems, due to limited volumes. One of the aims of plastic recycling is to reduce the need for virgin fossil-based plastics. Reports of Plastic Recyclers Europe[7] show increasing recycling rates. However, recycled HDPE and PP rigids from post-consumer products only meet

[6] At present, alginates as feedstock represent a very tiny share, so they are not included in this table.

[7] https://www.plasticsrecyclers.eu/publications/

approximately 11 % of demand for HDPE rigids (total European demand in packaging 3.4 Mt in 2023) and 9 % of demand for PP rigids (total European demand in packaging 2.9 Mt in 2023). Recycled HDPE and PP are mainly used in constructions (piping or sheet) and in electrical and electronic equipment. For PET, figures are more positive. Recycled PET met about 26 % (1.4 Mt) of the net annual European PET demand in 2021. The increasing pressure on higher recycling rates risks to enhance the production of mixed recycled plastics with limited applications and low market appeal [7]. By contrary, bio-based polyesters (like PEF and PLA) could help **increase the recyclability** of plastic, because of their versatility at end-of-life stages.

Environmental impacts

The environmental impact of bio-based plastics depends heavily on feedstock sources (e.g., waste/residues, agricultural, or forest materials). Agricultural and forestry residues and post-consumption organic waste have lower impacts than primary feedstock but face challenges in scalability due to collection and transportation complexities. Sustainable practices are critical to minimise land use and biodiversity risks. The competition for land and resources to meet the demands of food, feed, and industrial production highlights the need for efficient and sustainable use of biomass, in line with the cascading principle, which prioritises the sequential use of resources to maximise their value and minimise waste.

Life Cycle Assessment (LCA) methods are essential to evaluate environmental impacts, as they shed light on potential benefits and trade-offs across different impact categories throughout the value chain. According to some estimates, bio-based plastics currently are responsible for only 0.013 % of global land use[8], with minimal direct environmental impact. Their primary benefit lies in climate change mitigation through reduced CO_2 emissions and reduced fossil resource use, but there are trade-offs in impacts like eutrophication and land and water use [8].

Scaling up and innovation aspects

Many bio-based technologies remain at low Technology Readiness Level. Scaling up such technologies requires significant capital to create new infrastructures. A series of interviews with coordinators of relevant Horizon Europe projects, highlighted the key role that the policy can play. Targeted funding programs, leveraging on existing ones (e.g. Horizon Europe, Innovation Fund, Circular Bio-based Europe-Joint Undertaking) may help de-risk investments, providing support for industrialisation. Financial and market measures, like tax breaks, mandatory shares, and bio-based targets in legislation can attract private investment and help create demand. Streamlining authorisation processes for both building new production facilities and marketing new polymers is necessary to reduce the time to market and the related investment risk. Collaborations of start-ups and scale-ups with corporates could also drive market uptake and create stable offtake agreements. Finally, clear definitions, classifications and guidelines (e.g. on bio-based content, design-for-recycling, etc.) can reduce market uncertainty and create a level playing field.

Consumers' attitudes and expectations

Consumers' attitude is one of the key factors to increase the market share of bio-based plastics. On one hand, consumers increasingly prioritise sustainability [9][10]; on the other, they expect bio-based plastics to be as cheap and high-performing as fossil-based counterparts. Current bio-based plastic production costs are 1.5-2 times higher, creating a significant economic barrier. Some environmentally conscious consumers accept price premiums for bio-based products in applications with clear sustainability value. In fact, perceived environmental and safety benefits drive demand for compostable food packaging and personal care products. Other consumers expect brands to absorb the added costs of sustainability. Green policies like taxing fossil plastic or incentivising bio-based feedstock can help level the playing field. **Clear labelling, certification, and education** can foster informed decision-making. In fact, transparent and verifiable claims, harmonised standards and labels, and balanced data-driven approaches are necessary to address misconceptions and improve awareness, ultimately driving the adoption of bio-based plastics.

[8] https://www.european-bioplastics.org/agricultural-biomass-fuelling-the-shift-to-biobased-plastics/

Knowledge gaps

The following priority knowledge gaps have been identified, based on literature review and a stakeholder survey:

1. Limited understanding on how different bio-based plastic production pathways (bio-attributed/certified, bio-based drop-in, dedicated bio-based) affect biomass demand, land-use and broader sustainability trade-offs.
2. Need to enhance transparency and harmonisation of LCA methodologies for mass balance across feedstocks. Key gaps include up to date, comparable data, in particular for end-of-life performance, accounting methodologies for biogenic carbon and indirect environmental impacts (e.g., impacts on biodiversity at local scale).
3. Insufficient insights into industrial, market and value chain strategies for the deployment of sustainable plastics, including waste management practices and integration into existing recycling and waste management systems.
4. Fragmented and incomplete data on European production capacity, markets, and value chains for bio-based plastics.
5. Limited publicly available and peer-reviewed information on emerging bio-based materials and related frontier technologies, which are largely driven by industry.
6. Insufficient insights about the co-dependency in the production of energy and materials, concerning coordinated strategies to phase-out fossil feedstocks.

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