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Publication date
2024

Published in
PLATE 2023

Aalto University
School of Arts, Design and Architecture

PLATE
Product Lifetimes And The Environment

5th PLATE 2023 Conference
Espoo, Finland - 31 May - 2 June 2023

Drivers and barriers for bio-based plastics in durable products

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Keywords: Bio-based plastics; Drivers; Barriers; Circular economy; Durable products; Value chain.

Abstract: Bio-based plastics are gaining attention as a sustainable, circular alternative to the current, petrochemical-based plastics. The main application of bio-based plastics is in single-use packaging with short lifetimes. Extending the application of bio-based plastics products towards durable consumer products requires the involvement of different value chain actors. An online interactive workshop, with 46 participants representing the entire value chain, produced a list of drivers for using bio-based plastics in durable consumer goods and barriers to overcome. The primary barriers to using bio-based plastics in durable products were related to their underdeveloped value chain and a need for more knowledge. The underdeveloped value chain was associated with high costs and no infrastructure for recovery at end-of-life, reducing potential environmental benefits. Participants indicated that they did not expect the value chain to mature without substantial government stimulations. Participants also noted a lack of knowledge among value chain actors as well as end-users. Value chain actors expressed that they need more clarity about what bio-based plastics are available and how they can be used in a sustainable way. While the market demand for sustainable alternatives is growing and bio-based plastics are a valuable marketing tool, users are poorly informed, and marketing should be thoughtful to avoid greenwashing.

Introduction

Plastics are vital for modern life, but their environmental impact and damage caused by plastic pollution necessitate a new approach. Plastic production consumes up to 8% of fossil fuels extracted annually (Lambert & Wagner, 2017), while it is estimated that 79% of all plastic ever produced has accumulated in landfills and the natural environment (Geyer et al., 2017). Bio-based plastics have the potential to enable circularity since they are based (at least in part) on biomass, rather than finite petrochemical resources (International Standards Organisation (ISO), 2015). The renewable nature of bio-based plastics enables circularity at the plastic production level. While only accounting for 1% of all plastics produced in 2022, the market for bio-based plastics is growing at over three times the rate of that of petrochemical-based plastics (Skoczinski et al., 2023). The Circular Economy Action Plan contains plans to stimulate the bio-based sector (European Commission, 2020).

Bio-based plastics can be divided into drop-ins and dedicated bio-based plastics (Carus et al., 2017). Drop-in bio-based plastics are chemically identical to petrochemical-based plastics of the same name, such as polyethylene (PE). Dedicated bio-based plastics have no petrochemical-based equivalent. Biodegradable plastics are plastics that can be decomposed by living organisms and can be bio- or petrochemical-based. Not all bio-based plastics are biodegradable, although the two are often associated (Lambert & Wagner, 2017).

The main application of bio-based plastics is in single-use packaging with short lifetimes (Skoczinski et al., 2023). The application of plastics in single-use products will likely be limited by environmental legislation in the European Union (European Union, 2019) and other countries (Xanthos & Walker, 2017). The application of bio-based plastics may then shift towards durable products. However, applying bio-based plastics in products with extended lifetimes requires the involvement of value chain actors unfamiliar with these materials.

This study aims to unveil how bio-based plastics are perceived by actors throughout the value chain for durable consumer goods: in this case, the telecommunication sector. An interactive workshop produced a list of drivers for using bio-based plastics and barriers to overcome in order to extend the lifetime of bio-based plastic products from packaging towards durable consumer goods.

Methodology

In October 2020, 46 participants representing the entire telecommunications value chain attended an online workshop. Participants were approached through the network of a Dutch telecommunications company and that of the authors. Prior to the workshop, 39 participants filled out a survey about their role in their company and their experience with bio-based plastics. Table 1 contains an overview of the participants. Survey participants covered the entire value chain of telecommunications products, in addition to the fields of legislation and research. 26 out of 39 respondents were employed in a sustainability-related role.

Role	Number of responses
Design and/or development	10
Legislation	4
Management	10
Research	5
[illegible]	8
Sustainability	26
Other	1

Table 1. Overview of participants' role. Participants could select multiple answers.

During the workshop, the participants were given a brief introduction to bio-based plastics, followed by an interactive assignment. Participants were asked to fill out an online collaborative whiteboard with drivers and barriers to using bio-based plastics in durable products. Participants could place green dots on entries to mark them as important.

After the workshop, all entries were anonymised, and those not phrased clearly were removed. The remaining entries were independently coded by two of the authors and grouped into drivers and barriers. These drivers and barriers were developed into themes that describe the participants' attitudes towards using bio-based plastics in their durable products. To determine the perceived importance of each driver or barrier, the number of post-its corresponding to them was combined with the number of green dots they received.

Results

Prior knowledge of the participants

Figure 1 displays the outcomes of the pre-workshop survey. The majority of respondents rated their knowledge about bio-based plastics as low to very low. Most also had little to no experience working with bio-based plastics. 8% of respondents were already producing products containing bio-based plastics, and 77% of respondents considered it likely to very likely that they would do so in the near future.

Drivers and barriers to bio-based plastics usage

Drivers for bio-based plastics usage were categorised into the following seven themes: legislation, public perception, sustainability, design opportunities, sourcing, end-of-life, and collaboration. Below, the drivers for each theme are listed in order of perceived importance. It should be noted that the statements represent the participants' views and not necessarily the facts or the authors' views.

Driver theme 1: Legislation

- Existing and future regulations and sustainability targets could incentivise the use of bio-based plastics. For example, the European Green Deal, the Circular Economy Action plan, and CO2 emission targets.

Driver theme 2: Public perception

- Bio-based plastics can be used as a marketing tool to engage customers who are becoming increasingly environmentally contentious.
- Being an early adopter of bio-based plastics will reflect well on a company's image and establish them as a frontrunner.
- The interest in bio-based plastics in the corporate world is growing.
- Policymakers are driven by increased public awareness of environmental issues as well as business needs.

Driver theme 3: Sustainability

- Bio-based plastics can help companies to realise a circular business model.
- Bio-based plastics production can have a lower environmental impact than petrochemical-based plastics production.
- Bio-based plastics can be a sustainable solution for the long term due to their renewable resources.

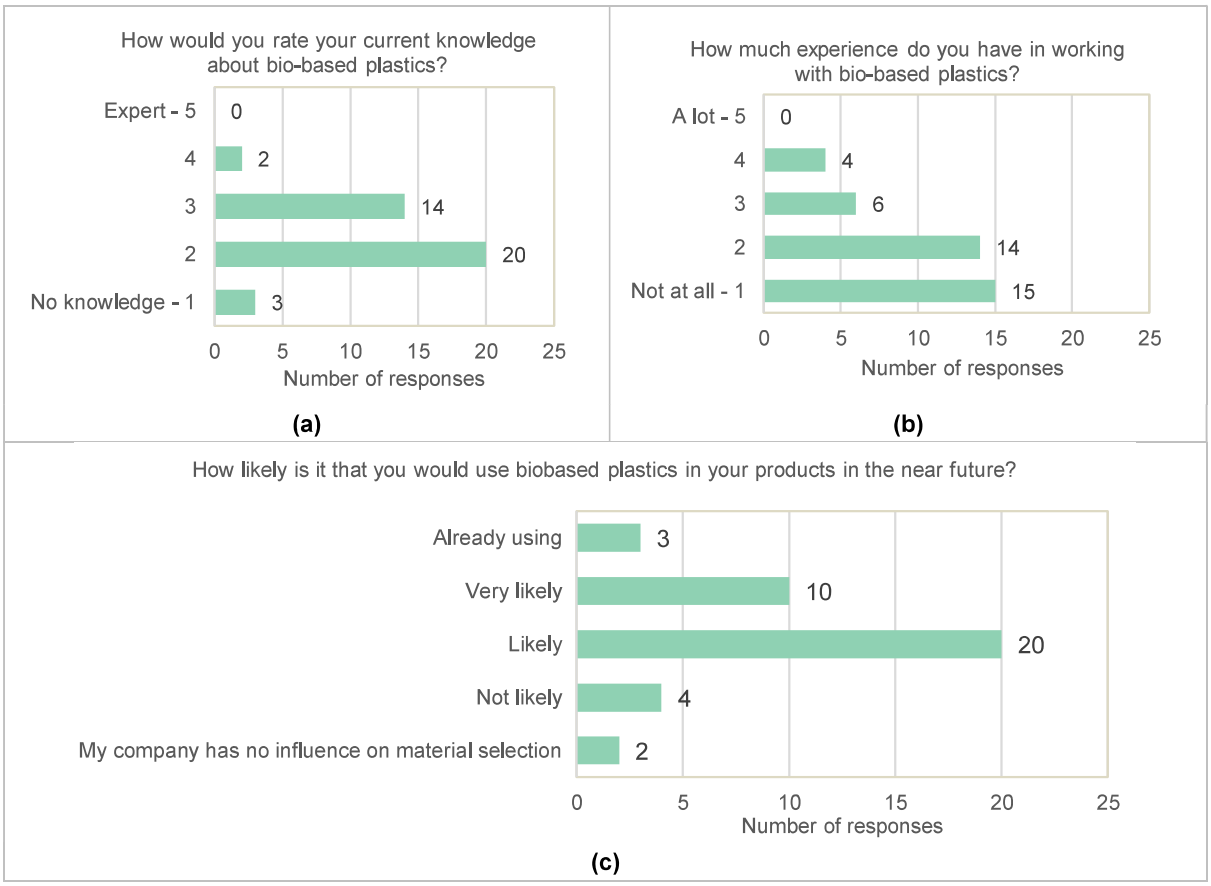

Figure 1. Outcomes of the pre-workshop survey about (a) prior knowledge of bio-based plastics, (b) prior experience with bio-based plastics, and (c) likeliness of using bio-based plastics in the near future.

Driver theme 4: Design opportunities

- Bio-based plastics can have new and unique properties that can be exploited in product design to add to performance and user value.
- Drop-in bio-based plastics can directly replace petrochemical-based counterparts, enabling a gradual transition.
- A new material creates the opportunity to experiment and develop new knowledge about its application.

Driver theme 5: Sourcing

- Bio-based plastics can be produced from a wide range of feedstocks, including waste, potentially resulting in a stable and local supply chain that is ultimately less dependent on fossil fuels.

Driver theme 6: End-of-Life

- Biodegradable (i.e. not per se bio-based) plastics can reduce waste and can be used to collect other compostable materials. For instance, biodegradable compost bags to collect home compost.
- Biodegradable plastics can provide a sustainable solution for products that wear or dissipate into the environment, such as tires or shoe soles.

Driver theme 7: Collaboration

- Being a new material, bio-based plastics allow for more interaction, knowledge sharing, and collaboration within value chains.
- Bio-based plastics can create new job opportunities.

Barriers to bio-based plastics usage could be categorised into the following seven themes: costs, lack of knowledge, sourcing, sustainability, end-of-life, an uncertain future and material properties. Below, the barriers for each theme are listed in order of perceived importance by the participants.

Barrier theme 1: Costs
- Bio-based plastics are more expensive than petrochemical-based plastics, increasing the price of a product.
- Users may not be able or willing to pay more.
- The entire value chain must change to accommodate bio-based plastics, which is expensive and time-consuming.

Barrier theme 2: Lack of knowledge
- Not all properties of new bio-based plastics are known. Bio-based plastics may have a lower technical performance than petrochemical-based plastics.
- Adding more variation in plastics adds complexity to proper disposal, making it confusing for end-users.
- It is risky to communicate bio-based with end-users because they do not have much knowledge about the concept, and the environmental benefits are still unclear.
- There are no clear guidelines on how to use bio-based plastics.
- Policy makers are not well informed about bio-based plastics.
- Bio-based plastics are not well known throughout the value chain. There is also insufficient information available.

Barrier theme 3: Sourcing
- Transitioning fully to bio-based plastics may not be possible without competing with food supply.
- The current volumes of available bio-based plastics are too low to cover demand and to enable recovery at end-of-life for dedicated bio-based plastics.
- Pollution from biomass may transfer into the plastic.

Barrier theme 4: Sustainability
- There are no standards for measuring and communicating the environmental impact of bio-based plastics and no policies regarding resource use, potentially leading to greenwashing.
- There is not enough clear information available about the environmental impact of bio-based plastics production and whether it is lower than petrochemical-based plastics.
- Marketing a product as more sustainable may cause end-users to adopt a less critical consumption attitude.
- Company image may suffer if bio-based plastics are derived from biomass that has damaging environmental effects.

Barrier theme 5: End-of-life
- Recovery of bio-based plastics at end-of-life is not yet guaranteed. Especially for dedicated bio-based plastics, production volumes are too small to facilitate reverse value chain infrastructure.
- The degradation levels of bio-based plastics compared to petrochemical-based plastics during recycling are unknown.
- Recyclability still needs to be guaranteed by product design.

Barrier theme 6: Uncertain future
- Certification of bio-based plastics can be complicated, taking years to develop.
- It is unclear how the market will develop, and governments are not taking an active role.
- There is a strong lobby of oil companies.
- Bio-based plastics are a rapidly developing field, which is difficult for companies.

Barrier theme 7: Material properties
- The aesthetics of bio-based plastics may be perceived as less desirable or of lower quality.
- Bio-based plastics properties may not meet material regulations such as fire safety or skin contact.
- Material composition and properties could vary depending on the source.

Discussion

Figure 2 presents an overview of the driver and barrier themes and illustrates the tensions between them. The observations are broadly in-line with pre-existing research. There is a tension between the positive public perception of bio-based plastics and their high costs. Bio-based plastics are more expensive than regular petrochemical-based plastics, which is often seen as a barrier (Álvarez-Chávez et al., 2012; Brockhaus et al., 2016; Rai et al., 2021).

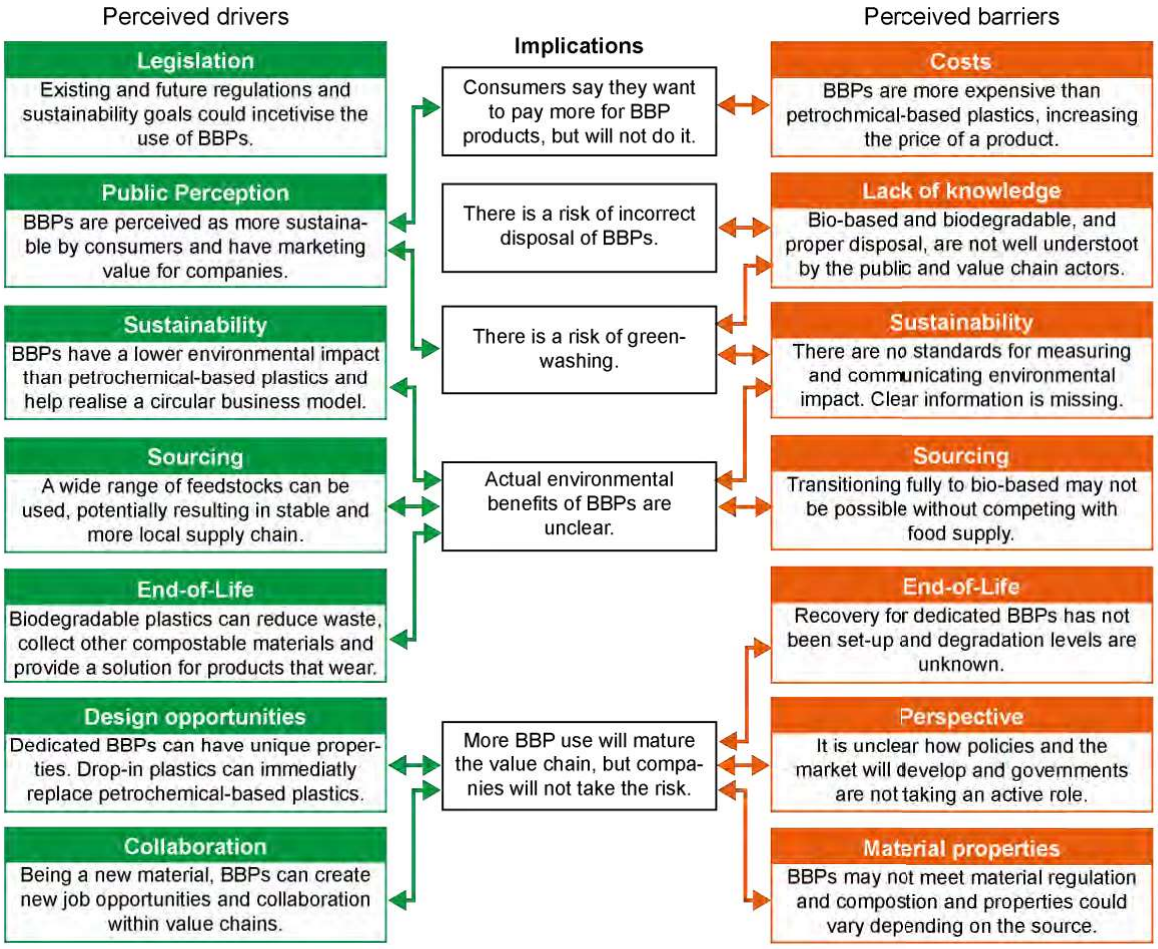

Figure 2. Overview of drivers and barriers for using bio-based plastics (BBP). Tensions between the drivers and barriers are highlighted in the middle column.

The public perception of bio-based plastics is positive, and consumers state that they would pay an increased price for a bio-based product (Kainz et al., 2013), but not everyone follows through on their stated willingness to pay more for a bio-based products (Barber et al., 2012; Prothero et al., 2011). This value-action gap is a common phenomenon for more sustainable products.

Despite their positive perception, the general public's knowledge about bio-based and biodegradable plastics is poorly developed (Dilkes-Hoffman et al., 2019). Using bio-based plastics could therefore be risky, according to the participants. The use must be communicated clearly to the consumer in order to justify an increased cost. When bio-based plastics are applied in durable products, the bio-based aspect is typically mainly reflected in marketing (Bos et al., 2022). However, the concept of bio-based plastics is complex, and the sustainability of the plastics is not entirely proven. This puts a company at risk of being accused of greenwashing.

The lack of public knowledge also extends to the recovery of bio-based plastics, combined with a lack of recovery infrastructure. Participants were concerned about proper disposal of bio-based or biodegradable products by end-users, and then by the reverse value chain. After use, drop-in bio-based plastics can easily integrate into existing recovery streams. However, these streams do not exist for novel, dedicated bio-based plastics, and there are no regulations or standards for their recovery at present (Briassoulis et al., 2019). Biodegradable plastics are not yet accepted in most industrial composting facilities (Álvarez-Chávez et al., 2012; Rai et al., 2021), and rarely fully disintegrate in home compost or nature (Lambert & Wagner, 2017). This creates the risk of doing more harm than good when using bio-based or biodegradable plastics.

Value chain actors themselves also lack knowledge about bio-based plastics. This already became apparent in the pre-workshop survey. Moreover, biodegradable plastics were often discussed during the workshop as if biodegradability is a property of bio-based plastics. However, biodegradable plastics are not necessarily bio-based, further highlighting the lack of knowledge and confusion. Furthermore, participants were not well informed about alternatives to the plastics used in their products. While bio-based packaging is already readily available, incorporating bio-based plastics in durable products requires the development of new knowledge.

Participants were divided on whether the environmental impact of bio-based plastics would be higher or lower than that of petrochemical-based plastics. Bio-based plastics are perceived to be more sustainable by many of the workshop participants as well as the general public (Brockhaus et al., 2016), but this is not yet confirmed by lifecycle assessment (Bishop et al., 2021; Walker & Rothman, 2020). Exploiting the sustainable image of bio-based plastics in marketing while the actual environmental impact remains uncertain can lead to greenwashing (Calero et al., 2021; Cardon et al., 2011; Nandakumar et al., 2021).

Most barriers and tensions appeared to originate in the immature value chain of bio-based plastics, which was considered a major barrier. During the workshop, this was labelled as an apparent causality problem, more commonly known as a chicken or egg problem. The immature value chain makes bio-based plastics expensive and poorly understood, resulting in unclear environmental benefits. The value chain cannot develop if bio-based plastics are not used more widely, but it is also a barrier to more widespread usage.

Conclusions

Although knowledge about and experience with bio-based plastics was low for most participants, they expected that bio-based plastics would be used in their durable products in the near future. Workshop participants reported legislation and public demand for more sustainable products as the main drivers for using bio-based plastics in durable products in the telecommunications sector. Some existing legislation already incentivises the use of bio-based plastics, but participants expected future legislation to further promote bio-based. Bio-based plastics can be valuable in marketing and design, but the lack of knowledge and confusing terminology surrounding them require careful consideration in order to avoid greenwashing.

The circularity and sustainability of bio-based plastics were seen as a driver as well as a barrier. Bio-based plastics are perceived to be more sustainable, but the environmental benefits of bio-based plastics production and upscaling are still debated. Many bio-based plastics cannot be recovered at end-of-life as of yet. Notably, sustainability was not considered as important of a driver as legislation and public perception.

If bio-based plastics are to find widespread usage in durable consumer products rather than single-use packaging, their value chain needs to grow, and information is still missing. The bio-based plastics value chain will not mature by itself but requires government stimulation. Furthermore, bio-based plastic packaging options are readily available, but applying bio-based plastics in durable products requires the generation of new knowledge. There need to be more resources about what bio-based plastics are available and how they can be used in durable products. The sustainability of bio-based plastics needs to be further studied: the environmental impact and the effects of land-use change due to upscaling are not clear at present. Recovery at end-of-life also needs to be guaranteed.

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