

Supplementary Materials: Interview results

This chapter provides a comprehensive description of the opportunities and barriers that emerged from the interviews and includes relevant quotes for clarification.

S.1. Formulating goals and strategies

Companies see the use of bio-based plastics as an opportunity to achieve their sustainable vision (**opportunity 1.1**). Their primary focus is on using renewable feedstock and thereby reducing the carbon footprint: *"If you just look purely at the LCA of the material, it is a lower footprint. So that is obviously a good thing"* (I.11). For some companies the use of renewable feedstock is enough argument to consider it sustainable. One interviewee mentioned that for them bio-based equals sustainable while, for example, durability and recyclability are a bonus: *"We tried to create two major or two main families, so durable and bio-based. At the moment the balance is more for durable"* (I.6). In their case the 'durable' products are made of a fossil-based plastic.

Although companies see limitations in current bio-based plastics, they are motivated to use them in their products. They see, for example, that recovery options are lacking and question the mass-balance approach, but they feel they need to take steps to shift away from fossil resources (**opportunity 1.2**): *"We were thinking of an approach that it is better to do something than nothing. And maybe everything is not perfect but at least we are doing something"* (I.10). Companies think this is needed to increase and improve bio-based plastic usage: *"About mass-balancing: of course that is not ideal, far from it. Because that cannot be explained, it is a vague kind of certificate system, but it is a kind of stepping stone to let that industry grow."* (I.11).

Companies see bio-based plastics as a means to sustainable sourcing in applications where recycled plastics are not permitted (e.g., food contact) (**opportunity 1.3**): *"We do have to deal with food safety, so then recycled plastic cannot be used because of safety reasons. Therefore biomaterial, yes in my eyes that is the most sustainable thing we can achieve at the moment"* (I.1).

Aside from the opportunities, companies perceive the lack of laws and regulations as a significant barrier to adopt bio-based plastics (**barrier 1.4**). For example concerning the differentiation between plastics, but also for end-of-life arrangements. Companies are waiting for rules, which slows development. The drive for sustainable solutions that include bio-based is currently mainly with the companies and there is no push from the government: *"We need to have laws and regulations to push forward. And then we have to develop clever solutions. [...] but it goes slow and it is, I mean just that how much percentage should it be bio-based to be able to call it bio-based plastic?"* (I.10).

S.2. Product designing & development

Opportunity 2.1 lies in companies utilising the aesthetics of the product to communicate the use of bio-based plastic, primarily through the use of colour. Companies make a distinction in appearance mainly to show the difference from fossil-based products (thus explaining the price difference) and for marketing reasons, rather than for functional purposes: *"It was designed to have kind of a natural look and feel. We did it because we wanted to tell a story with the product"* (I.11).

With the emergence of more and higher quality bio-based plastics in the market, companies see more opportunities to use them (**opportunity 2.2**). In particular drop-in plastics that can replace equivalent fossil-based plastics without requiring a change in the design process (**opportunity 2.3**): *"There is a good evolution in the biomaterials, which means that it today can make things which are*

quite close to the virgin [fossil] materials and even completely sort of touch and feel the same way” (I.4). However, because bio-based plastics are evolving, it also means that they can become quickly outdated, requiring companies to stay up-to-date with the latest developments in order to remain competitive: “We changed our materials in 2018 [...] Of course the reality is something else today and so you have to follow. Because you take your decisions upon what you know in that certain time and then it develops and then you have to follow, otherwise you will be left behind” (I.10).

Dedicated bio-based plastics can offer unique advanced properties that can be used in a product (**opportunity 2.4**). This gives opportunities, for example, in the functionality of a product: *“In some cases, of course, the bio-based plastic can also have an advanced property. Then with PE it is not necessarily so, but for example PEF indeed, those barrier properties [are better than PET] and then you have a different business case” (I.5).*

However, the application of bio-based plastics in the design and development process is not without its challenges. One issue is that product developers question whether bio-based plastics are truly a sustainable material choice (**barrier 2.5**). One example concerns the recyclability of bio-based plastics products: *“We have 60% bio-based PP and 40% wood fibre in those products. So when it comes to carbon footprint, from the manufacturing of the polymer to our production and then to the usage of the product by the customer, I think it is a good thing. But what I do not know about this product is what happens when they throw it away” (I.7).* A second example concerns the fact that there is often only one manufacturer of a particular bio-based plastics, and therefore the overall impact of transportation can be higher: *“The great example is PLA which was sometimes made in Brazil and then shipped to India for some kind of processing and finally went to a factory in Europe and had been all over the world twice before it finally got to the product” (I.11).* Other examples include food competition, land use, and the fact that bio-based plastics do not solve the waste problem since the same amount of waste is still produced compared to using fossil-based plastic.

The unknown properties of a new material are a challenge for the application of all new plastics because research and development is expensive and time consuming (**barrier 2.6**): *“Sometimes the material properties are still different, so for example, if we are going to produce a new product through injection moulding, the shrinkage margins, for example, are not yet known [...] Yes, we can guess and make an estimate, but really the numbers of that, such as plastic that has been on the market for years, that information is just not there yet” (I.1).*

Companies avoid using biodegradable plastics in durable products because they are concerned that they will decompose in the use phase (**barrier 2.7**): *“Biodegradable you do not want either, because then the cup will fall apart after 5 years” (I.2).* It seems like not everyone fully understands the concept of biodegradable. For this to happen, the exposure conditions like the temperature and humidity must be right (Lambert and Wagner, 2017), and these conditions are usually not present during normal use.

Despite the evolution of bio-based plastics, the perception of companies is still that there is a limited choice and therefore companies find it difficult to find the right plastic for their application (**barrier 2.8**): *“And many [options] are often dropped. Especially in transparent materials. [...] A more rubbery material and a transparent one are both not there yet” (I.8).* The question is whether companies are familiar with all the options and if they are available to them: *“There is another material from a supplier that we want to try out [...] But we do not get it. Probably it is because they have not developed it really yet. But they say, “yeah, we have it, we have it”, but it is not really there in the process or it takes longer or whatever” (I.10).*

5.3. Marketing planning

The market for bio-based plastics is growing (**opportunity 3.1**). Several interviewees indicated changes in consumer attitudes towards these products in recent years: *“About 7 years ago, I think, we first started with a tableware line in PLA. [...] And it flopped. People just thought, yeah, I will just buy a product made of PP or PS. And what is the difference except the price sticker being so high? [...] Two years ago, we thought, well, it has evolved again. We just have to pick it up again. Also because the other line of [brand] was successful, so we knew we had hit a market”* (I.2). Literature seems to confirm this finding. An online survey conducted among consumers from 17 countries shows 85% of consumers have become more environmentally conscious in their purchasing in the past five years (Simon-Kucher & Partners, 2021).

Companies see possibilities to highlight the sustainability of bio-based plastics in their marketing strategy (**opportunity 3.2**). Interviewees say that using bio-based plastics is good for marketing: *“It [the mass balance approach] does not affect the end product for us, as long as you keep the same polymer, it is the same. But of course it is much better to say that we have 70% renewable material feedstock in our products.”* (I.9) One interviewee initially emphasised sustainability in their marketing, but later shifted to highlighting safety: *“We quickly understood that it did not matter, nobody cared that they were environmentally friendly. [...] We said okay, what would sell? [...] Then we switched the message to safety. And to this day I believe that, from a chemical point of view, we made the safest baby toys that were ever made, because it was 100% bio-based. We literally had no petrochemical additive in it, so it was totally free of petrochemical toxic elements”* (I.3).

Consumers' lack of understanding about bio-based plastic and their differences from fossil-based plastics is a significant barrier for companies (**barrier 3.3**). *“I think people just do not understand it. We got the question: can you eat it now that it is made of sugarcane?”* (I.5). Companies find it difficult to explain the concept of bio-based plastics in their marketing. Misunderstanding among consumers gives risks of, for example, improperly dispose of products: *“And then also you might give the false impression to the consumer that you can throw plastic around you and it will disappear and that is not nice”* (I.4).

Companies say that consumers are reluctant to purchase bio-based plastic products due to the higher prices (**barrier 3.4**): *“You ask them: would you buy a bio-based product which costs 20% more than the normal one? Everybody says yes when they fill in the questionnaire, but then when you do the shopper study no way”* (I.4). This phenomenon, known as the value-action gap, where the willingness to behave more sustainable is not necessarily reflected in the actual behaviour, is common for sustainable innovations (Barr, 2006; Young et al., 2010).

Marketing bio-based plastics as sustainable and safe can backfire and ultimately harm the company's reputation (**barrier 3.5**). It might be tempting for companies to seek or even cross the limits of what can be considered the 'truth', as the consumer market is easily persuaded to believe a sustainability claim. *“That is a bit the boundaries marketing always seek, because you do not want to do Greenwashing, but you do want to have a sharp claim”* (I.11). Companies seem to be aware, however, of the potential for false claims to backfire: *“They came to us and said, we would like to use this Castor oil based material due to marketing reasons. I was like, that is stupid, do not do it. It does not matter because if somebody is really looking into the product, you will fail”* (I.12).

S.4. Production

The mass balance approach is viewed as an opportunity by companies, as it enables them to continue using the same production and certification processes they are accustomed to, while gradually transitioning bio-based (**opportunity 4.1**): *“We found out over time is to replace today's materials with the real, like from the common understanding, bio-based polymer, it will not be possible. Therefore we use this what we call the biomass balance approach to somehow shift our own production from a feedstock which is based on gas and crude oil to a natural or bio-based resource”* (I.12).

An often mentioned barrier is the fact that bio-based plastics are more expensive than fossil-based ones (**barrier 4.2**). Therefore the products become more expensive and this links to barrier 3.4: consumers are not willing to pay more: *“Well, the problem is price right now. So it is really substantially more expensive, so that is why companies also have to make it a commercial success”* (I.11). Also for the mass balance certificate an extra premium is paid: *“The fossil based would cost us roughly about €2.00 right now for that PP and there is an additional cost for a mass balanced bio-based, maybe around €1.00”* (I.7).

Bio-based plastic producers currently have monopolies on the market, which can be difficult for companies that want to use bio-based plastics in their products (**barrier 4.3**). Because there are limited suppliers, companies have little control over the sustainability of the bio-based plastics (e.g., the feedstock used or the location of production). Additionally, the limited supply and production of bio-based plastics can make them hard to obtain and lead to higher prices: *“The problem with it again is that supply is tight and it is tied to there is only one or two suppliers and you are at their whim basically. And mostly it is not a standard scaled product, you know, they produce a few batches now and then and they push it in the market. So it is not scalable”* (I.3).

Using new plastics bring challenges in the production process (e.g., different mould and processing conditions and compound variations) (**barrier 4.4**). This barrier is not unique to bio-based plastics, as every new material or plastic grade can pose production challenges. Although one interviewee mentioned that in his experience problems due to low melting temperatures are a common issue with bio-based plastics: *“I think the melting point of bio is sometimes surprisingly low, which means that you can burn the material in the process. And when something burns in the process, it not only means that it smells bad, but it also clogs the machine and the filters and everything. And you might have a day of maintenance and that day of production you could do quite a lot of value which you cannot do if you run into trouble”* (I.4).

S.5. Recovery

An opportunity and therefore driver for companies to use bio-based plastics is the fact that they have a lower carbon footprint than fossil-based plastics (**opportunity 5.1**). This reduced carbon footprint is mainly attributed to the fact that bio-based plastics sequester carbon dioxide during the growth of the biomass used as feedstock. As a result, the footprint, including recovery, is lower than if fossil-based plastics had been used: *“When it comes to carbon footprint, from the manufacturing of the polymer to our production and then to the usage of the product at the customer, I think it is a good thing”* (I.7).

Consumers are uncertain about how to dispose of bio-based plastic products after use (**barrier 5.2**). This barrier relates to consumers' lack of knowledge and understanding of bio-based plastics and their recovery options (barrier 3.3). Because consumers do not know how to deal with bio-based plastics after use, the ultimate end-of-life of these products is unpredictable. This

uncertainty can lead to consumers improperly disposing of bio-based plastics and potentially causing harm to the environment: *“Many people still think that if you are dealing with bio plastic, it disappears when you throw it into nature”* (I.1).

There is no infrastructure to recycle new plastics and this makes recycling dedicated plastics a challenge (**barrier 5.3**). Some interviewed companies therefore prefer to use drop-in plastics that can be recycled in existing recycling streams: *“We want the products to remain recyclable. So the materials we use must also be recyclable in the end. So where possible it should just be drop-in replacement for a PP, an ABS, and materials like that. And PLA as a replacement for ABS in electronics is not a sustainable option in our opinion. Because that PLA can technically be recycled, but we currently know that it is not”* (I.11). Furthermore, other recovery pathways like composting are not available everywhere in the world, which makes it less likely for companies to consider it as an end-of-life option when selling products internationally: *“We do not have industrial composting in [country] and in many countries it is like that. [...] it is also hard to communicate. Yeah, you can compost it, but you cannot. And you have to put it in the normal trash anyway”* (I.10).

References

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