Biobased plastics in vehicles

Including biobased in a circular plastic obligation for vehicles

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Content

Summary

The European Commission would like to see an increase in the use of circular materials in vehicles to limit the import and use of primary plastics, metals and critical raw materials. For plastics, a mandatory minimum target of 25% for the use of recycled plastics is being considered as part of the proposal for a regulation on circularity requirements for vehicle design and on management of end-of-life vehicles (EC, 2023b).

However, in addition to recycling, biomass can also be used to produce circular, non-fossil plastics. In this study, we explore the technical possibilities, greenhouse gas (GHG) emissions and policy considerations of a mandatory target for biobased plastics in vehicles. This could be done as a separate target or as a combined target with recycled plastics.

Why consider adding biobased plastics to the target for recycled plastics?

There are a number of reasons to include biobased plastics in the obligation. Vehicle manufacturers have more options to meet the target(s) when they can also use biobased plastics. For some car parts, mechanically or chemically recycled plastics may be most suitable (e.g. from technical performance, cost and availability perspectives); for others, biobased plastics may be a better alternative. By including more options for circular plastics, the EU can move beyond the 25% target e.g. for 2040 or 2050.

What does the current plastics use in vehicles look like?

JRC research found that six polymer types account for over 80% of EU plastics use in cars. These are PP, PUR, PA, PE, ABS/SAN, and PET[1]. About 2,200 kilotonne plastics are used in EU vehicles (cars, light commercial vehicles and motorcycles) each year. The automotive sector represents 8% of the EU plastics demand.

To what extent can biobased plastics replace fossil plastics in vehicles?

A range of (partially) biobased plastic alternatives are available, which can replace most of the main fossil plastics currently used in vehicles directly (drop-in biobased plastics). This is the case for bio-PE, bio-PP, bio-PET and bio-ABS. In addition, different grades of bio-PA and bio-PU are available which are either already used in cars or are likely suitable. Finally, bio-PTT and bio-PLA are novel biobased plastics that are also already used in cars.

Together, these biobased plastics give a wide range of options for vehicle manufacturers. As a rough first estimate, the current technical substitution potential of biobased plastics is about 70%. Considering the availability of biomass and production capacity forecasts, substituting about 5% to 10% of the current fossil plastics in the EU vehicles seems feasible on the short term. While this would provide a strong stimulus for biobased plastics, the EU's support for biofuels is much larger. Even at 10% substitution, the market for biobased plastics would be 20 times smaller than the EU's ethanol biofuel market.

[1] Polymer abbreviations: Polypropylene (PP), polyurethane (PUR), polyamide (PA), polyethylene (PE), acrylonitrile butadiene styrene/styrene acrylonitrile (ABS/SAN), polyethylene terephthalate (PET), polylactic acid (PLA), polytrimethylene terephthalate (PTT).

How sustainable are biobased plastics?

Biobased plastics are one of three types of circular plastics, along with recycled plastics and plastics produced from captured carbon. Biobased plastics can offer lower GHG emissions than fossil plastics, which can be assured by requiring a minimum GHG emission reduction calculated with a uniform methodology. In addition, since biobased plastics often use agricultural land, there are risks of land use-related environmental impacts (e.g. biodiversity loss). These should be avoided by using sustainability criteria for biomass. This approach is in line with the EU's support for biofuels in the Renewable Energy Directive.

Depending on the extent to which biobased plastics would substitute fossil plastics and the minimum GHG emission reduction requirements, yearly GHG emission reductions over 200 kilotonne CO_2-eq. are possible (based on 10% biobased plastics in vehicles and 1 kg CO_2-eq. reduction per kg plastic).

Biobased plastics are just as recyclable at end-of-life as fossil plastics. However, the infrastructure for plastics recycling in general is limited in the automotive industry at the moment. To maximise end-of-life recycling rates, the recycling infrastructure should be established taking into account the polymer types used in vehicles (regardless of whether they are fossil, recycled, drop-in biobased, or novel biobased).

Policy considerations

Since there are suitable biobased plastic options available to substitute the fossil plastics currently used in vehicles and substantial substitution rates (e.g. 5 to 10%) are possible, policymakers can consider establishing a biobased content target for vehicles. This can result in substantial GHG emission savings, although a uniform calculation method and additional biomass sustainability criteria are needed.

A circular plastics target for vehicles can be shaped in different ways:
1. **Target for recycled plastic only**: Vehicles must contain at least 25% recycled plastic.
2. **Separate targets for recycled plastic and biobased plastic**: Vehicles must contain (for example) at least 25% recycled plastic and 5% biobased plastic.
3. **Combined target**: Vehicles must contain at least 25% recycled and/or biobased plastic.
4. **Combined target with a cap on biobased**: Vehicles must contain at least 25% recycled and/or biobased plastic. Biobased plastics account for at most (for example) 10%.

If biobased plastics are included, vehicle manufacturers have more flexibility to choose the most appropriate/cost-effective materials. This can mean the targets can be met at a lower cost to manufacturers and price shocks can be more easily absorbed. For policymakers, a combined approach creates a more level playing field for circular plastic options. An additional advantage is that the transition to circular plastics becomes less reliant on the availability of waste plastics for recycling. Overall, by including biobased plastics, the circular plastics target becomes easier to achieve.

Including biobased plastics in the target now (even if capped at a small percentage) will send a strong signal that the EU is looking beyond a single technological solution to move away from fossil plastics in vehicles. This will prepare vehicle manufacturers, plastic producers and recyclers for a future situation in which a variety of circular strategies will be needed to ultimately reach 100% circular plastics in vehicles and other products.

1 Introduction

The European Commission would like to see an increase in the use of circular materials in vehicles to limit the import and use of primary plastics, metals and critical raw materials. Circular plastics are made from non-fossil resources, such as discarded plastics (recycled plastic), biomass (biobased plastic) or captured CO_2.

For plastics, a mandatory minimum target of 25% for the use of recycled plastics is being considered as part of the proposal for a regulation on circularity requirements for vehicle design and on management of end-of-life vehicles (EC, 2023b). Around 2,200 kilotonne (ktonne) of plastics is used in cars, vans and motorcycles put on the EU market each year[2]. The plastic consumption of vehicles is however expected to keep growing. 2,200 ktonne corresponds to roughly 4% of total plastic consumption in the EU (Plastics Europe, 2022b). A recycled plastics target of 25% would mean that around 550 ktonne of recycled plastics are required each year.

In addition to recycling, biomass can also be used to produce circular, non-fossil plastics. The use of biomass to produce plastics reduces the consumption of fossil fuels for plastic production. Similar to recycled plastics, biobased plastics can also offer reduced greenhouse gas emissions compared to fossil plastics.

It is therefore relevant to consider the effects of including biobased plastics in the current proposal for a mandatory target for recycled plastics in vehicles. If the 25% target for recycled plastic in vehicles could also (partly) be met with biobased plastics, it can become easier for vehicle manufacturers to achieve the obligation. This could increase the acceptance of a target for non-fossil plastics in vehicles and lower costs. It could also help to establish a more level playing field between the use of biomass for plastics and for biofuels (as covered in the EU's Renewable Energy Directive).

Research goals and policy options

The aim of this research is to assess whether biobased plastics can be used to substitute a substantial (i.e. 5 to 10%) share of fossil plastics currently used in vehicles, to provide a high-level estimate of the potential GHG emissions of such a substitution, and to discuss relevant policy aspects of including biobased plastics in the circular plastic target for vehicles.

The 25% target for recycled and/or biobased plastics in vehicles can be shaped in different ways. The options include:

1. **Target for recycled plastic only**: Manufacturers are obligated to use at least 25% recycled plastic in all vehicles.
2. **Separate targets for recycled plastic and biobased plastic**: Manufacturers are obligated to use (for example) at least 25% recycled plastic and 5% biobased plastic in all vehicles.
3. **Combined target**: Manufacturers are obligated to use at least 25% recycled and/or biobased plastic in all vehicles.

[2] See details in Chapter 2.

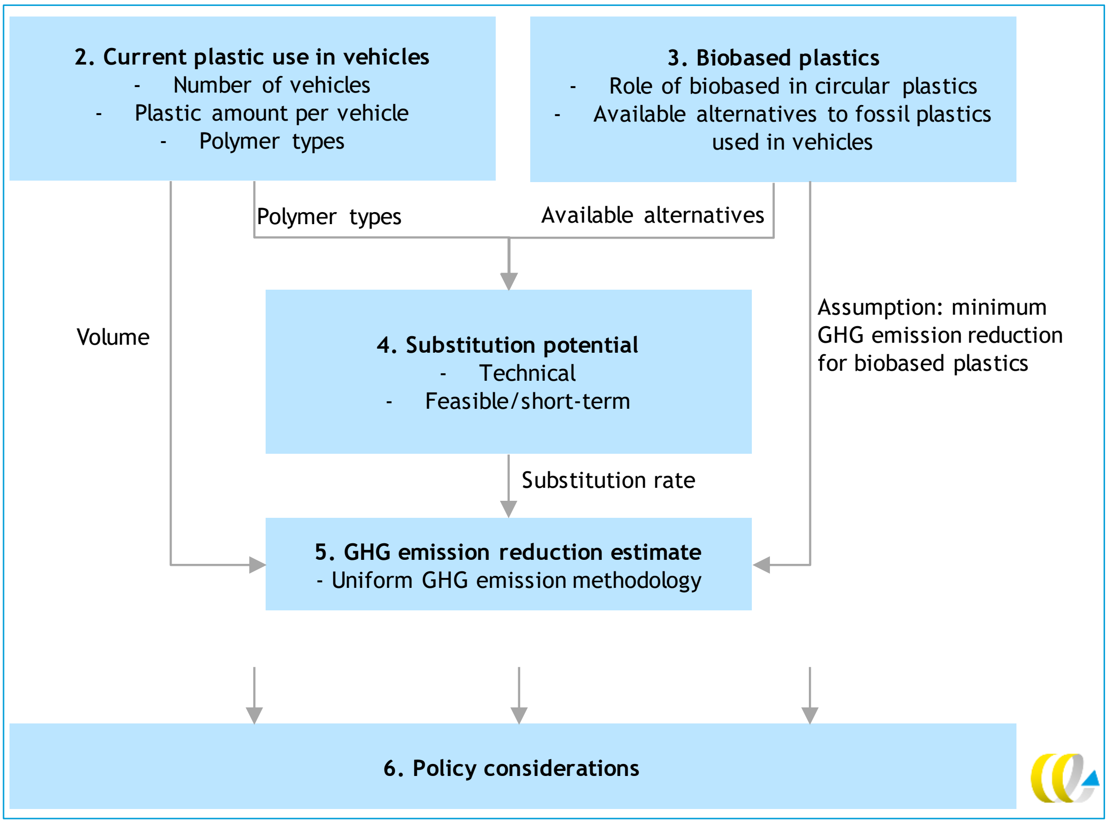
4. **Combined target with a cap on biobased**: Manufacturers are obligated to use at least 25% recycled and/or biobased plastic in all vehicles. Biobased plastics can account for at most (for example) 10% of the target.

These options are further discussed at the end of this report.

Approach and scope

Figure 1 provides a schematic overview of how the research is structured. The numbers correspond to the chapters in this report. All research questions are addressed through literature study. As there are uncertainties (e.g. on which plastics are used in motorcycles or related to claims on the GHG emissions performance of new biobased plastics), assumptions are sometimes made. These are clearly noted in the text.

Figure 1 - Research structure. The numbers correspond to the chapters in this report



The following can be remarked on the study's scope and approach:
- The research focuses on new vehicles put on the European Union market in the current situation and near future (e.g. 2030).
- Biobased plastics include both drop-in and 'novel 'biobased plastics. Drop-in biobased plastics are chemically identical to existing fossil plastics but derived from biomass. Novel biobased plastics exist of polymers that are not (normally) produced in fossil production routes. Both fully and partially biobased plastics are included.
- In the context of this study, 'vehicles' refers to cars, light commercial vehicles (vans) and motorcycles.

- In line with a recent JRC study, ‘plastics’ includes the standard and engineering thermoplastics used in vehicles, excluding rubbers (e.g. tyres), coatings, thermosets and composites. This means that the amounts of biobased materials that are used in cars is potentially already higher (e.g. tyres made from natural rubber) and can become even higher than the estimates in this report show.
- Additives used in plastics are not considered.

2 Current plastics use in vehicles

To estimate the substitution potential for biobased plastics, we first consider the current fossil plastic use in vehicles. In light of the recycled plastics content targets in vehicles, the EU's Joint Research Centre (JRC) has recently compiled information on the weight and composition of plastics in vehicles (JRC, 2023).

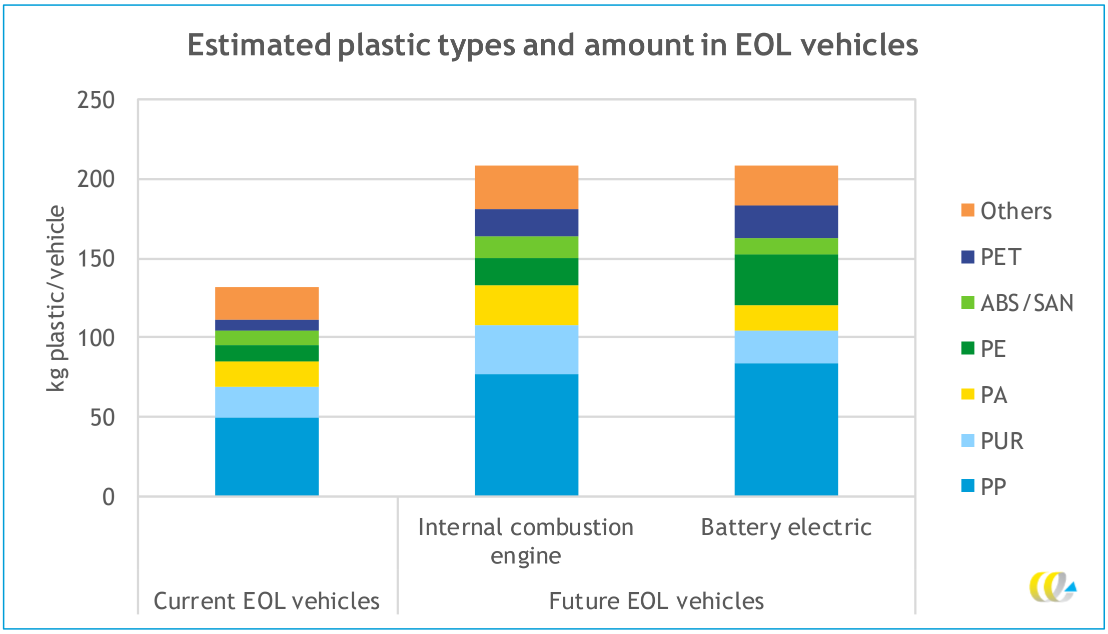
Plastics are used in many components of vehicles. The main applications of plastics in vehicles are bumpers, dashboards, headliner (ceiling cover on inside of vehicle), seats, carpets, headlight covers and many other small components.

Six polymer types account for over 80% of EU plastics use in cars

As shown in Figure 2, six polymer types account for about 84% of plastics use in current and future vehicles according to the JRC. These are PP (polypropylene), PUR (polyurethane), PA (polyamide), PE (polyethylene), ABS/SAN (acrylonitrile butadiene styrene/styrene acrylonitrile) and PET (polyethylene terephthalate). In the next section, we therefore focus primarily on biobased plastic replacements for these six fossil plastics.

Current end-of-life (EOL) vehicles (produced 15-25 years earlier) contain about 132 kg of plastics per vehicle. This is expected to increase to about 208 kg of plastics in both future internal combustion engine vehicles and battery electric vehicles (Table 1). This is in line with the trend of vehicles increasing in size while using more plastic as a lightweight material.

Figure 2 - Estimated plastic composition of current and future EOL cars and light commercial vehicles, kg/vehicle



Source: JRC (2023).

For reference, the values shown in Figure 2 are summarised in Table 1. A number of remarks are in order here:
- The results in Table 1 are representative of passenger cars and light commercial vehicles (LCVs).
- The JRC study includes ‘standard and engineering plastics’ as well as polyurethane foams. Standard plastics include PP, PE, PET, PVC and PS, engineering plastics are more specialised PA, PC (polycarbonate), POM (polyoxymethylene), PBT (polybutylene terephthalate), styrene co-polymers such as ABS, SAN and PMMA (polymethylmethacrylate), and other high-performance polymers. Elastomers, such as the rubber used in tires are not included. Similarly, thermosets, adhesives, coatings and sealants as well as composite materials such as plastics reinforced with carbon fibre or glass fibre are excluded from the JRC study and this analysis.
- The shares of plastics from the JRC are shares for EOL vehicles. We assume that the future EOL vehicles are comparable to future production.

Table 1 - Estimated plastic composition of current and future EOL cars and light commercial vehicles

	Current EOL vehicles	Future EOL internal combustion engine vehicle	Future EOL battery electric vehicle
Weight of the vehicle, kg	1,100	1,300	1,600
Of which plastics	12%	16%	13%
Weight of plastics, kg	132	208	208
Polymer types			
PP	37%	37%	40%
PUR	15%	15%	10%
PA	12%	12%	8%
PE	8%	8%	15%
ABS/SAN	7%	7%	5%
PET	5%	8%	10%
Others	16%	13%	12%

Source: JRC (2023).

About 2,200 ktonne of plastics are used in EU vehicles each year

In 2022 more than 11 million new vehicles were sold in the EU. The total amount of plastics used in vehicles put on the EU market is estimated at over 2,200 ktonne/year, as shown in Table 2. This includes vehicles imported to the EU. The current trend is that vehicles are becoming heavier and will have a higher share of plastics (see Table 1). If this trend persists, plastic use will increase over time.

Table 2 - Yearly plastic use in new vehicles in the EU

	Passenger cars[a]	Light commercial vehicles[b]	Motorcycles[c]	Total
Plastics weight, kg/vehicle	208	208	25	n.a.
Vehicles sold in EU, vehicles/year	9,276,510	1,278,509	1,158,119	11,713,138
Plastics use in vehicles ktonne/year	1,930	266	29	2,224

a) Plastic weight based on JRC, future vehicles. Vehicles sold is based on 2022 data retrieved from Eurostat (Eurostat, ongoing-b).

b) Plastic weight based on JRC, future vehicles. Vehicles sold is based on 2022 from ACEA, yearly registrations for EU of LCV <3.5t (ACEA, 2023).

c) For motorcycles the average weight was assumed to be 250 kg with a 10% share of plastics. Number of vehicles sold is based on 2022 data retrieved from Eurostat (Eurostat, ongoing-a).

The maximum potential of recycled plastic is limited

Across all product applications, plastics currently used in the EU are about 12% circular/ produced from non-fossil resources (Plastics Europe, 2023). Mechanical recycling of waste plastics packaging contributes most to this target, and there is a small role for biobased plastics (about 1%).

It is plausible that the total market share of recycled plastic can be expanded to e.g. 30 to 35%, although this would take considerable efforts (CE Delft, 2022a). As explained below, key limitations for recycling are the limited availability of waste plastics for recycling (plastics are being stored in the economy and plastic use in long life products is increasing) and losses during recycling itself. Transitioning towards circular plastics will therefore require other production routes alongside recycling.

Textbox 1 - Limits on maximum utilisation of recycled plastics

There are two main technological limitations that affect the maximum potential for recycled plastics:

a) The amount of plastic waste available for recycling is limited; and

b) There are plastic losses and quality degradation issues during recycling.

The first limitation stems from our growing use of plastics. Many plastics are used in long-life applications such as vehicles, but also in construction and electronic equipment. This means that the size of the plastic stock which is 'stored' in the economy is growing, and that the amount of waste plastic available for recycling is smaller than the amount of plastics needed for new products. In the Netherlands for example, about 2 million tonnes of new plastics are used each year, and about 1.1 million tonnes of waste plastics are generated[3]. Also in cars, the amount of plastic used is still increasing. The growing use of plastics and the time delay between use and availability for recycling at EOL limit the extent to which recycled plastics can meet the demand for new plastics.

The second limitation is that not all waste plastic can be converted into new plastic. In the current mechanical Recycling systems for plastic packaging, plastic is lost during collection, sorting and recycling itself. Losses can for instance occur when plastics are not put into the right waste streams, when they are combined with other materials (e.g. biomass contaminations) or when there are no sorting machines set up to separate the specific plastic type. Beyond the packaging sector, recycling of plastics is still relatively limited. However, also here losses can be expected.

In addition to physical losses, mechanical recycling can reduce the quality of the plastic. If there are contaminations in the plastic feed for example, these can end up in the recycled plastic resulting in lower quality material compared to primary plastic. Even very homogenous plastic streams, such as PET bottles collected from deposit schemes, can only be recycled up to 10 times due to quality losses. Some novel chemical recycling technologies can remove impurities from the waste plastics and create virgin-quality recycled plastics. However, these technologies still have plastic losses, which can be as high as 50% when considering the entire waste plastic-to-new plastic recycling chain (CE Delft, 2022b).

[3] www.plasticseurope.org/nl/2022/07/11/nederland-europees-koploper-in-recycling-plastic-afval-maar-verbrandt-ook-55-van-ingezameld-plastic-afval/ (Only in Dutch).

3 Biobased plastic alternatives

Here we discuss biobased plastics as an alternative to the currently used fossil plastics. We first briefly introduce biobased plastics and how they could supplement recycled plastics in circular vehicles. Then, we provide an overview of available biobased plastics to identify which options are available and which fossil plastics they could replace.

What are biobased plastics?

Apart from recycled plastic, other circular plastic options are biobased plastics and plastics made from captured carbon. Biobased plastics are made from biomass resources, such as crops grown on agricultural land (e.g. sugarcane, maize, castor beans), biological waste streams or byproducts (e.g. used cooking oil, tall oil, sewage sludge), or wood from forestry. Most currently available biobased plastics use the same biomass feedstocks that are also used to make biofuels, such as sugar and starch (see also Table 3).

Many biobased plastics (‘drop-ins’) have the same chemical structure as fossil plastics, bio-PP is identical to fossil PP, for example. This means they can directly replace fossil plastics in products and fit into the same recycling infrastructure at end-of-life. Others (‘novel biobased plastics’), such as PLA or PTT, utilise the chemical structures found in nature. Novel biobased plastics use polymers that are not produced via fossil routes and offer alternative material properties.

Recycling of biobased plastics at end-of-life

From a circular economy perspective, biobased plastics used in vehicles should be recycled at end-of-life, just like fossil plastics. At present however, recycling of plastics used in the automotive sector is limited in general. According to Plastics Europe (Plastics Europe, 2022a), the treatment of post-consumer plastics waste from the automotive sector is currently as follows (2020 data):
- landfill: 39%;
- incineration with energy recovery: 42%;
- recycling: 19%.

This shows that the infrastructure required to recover and recycle plastics from vehicles largely still needs to be established[4]. Drop-in biobased plastics have the same chemical structure as fossil plastics and can therefore be converted into the same (mechanical or chemical) recycling technologies. There are biobased drop-ins available for most of the fossil plastics currently used in vehicles (further discussed below). The recycling infrastructure for the most common of these plastic types (e.g. PP, PE and PET) already exists for plastic waste in the packaging sector. The same processes can in principle be used for plastic waste recovered from vehicles.

[4] For reference, the packaging sector has the highest recycling rates of plastics. There the distribution is 17% landfill, 37% energy recovery and 46% recycling (Plastics Europe, 2022a).

Novel biobased plastics have a different chemical structure than fossil plastics, but this does not mean that they cannot be recycled. PLA, for example, can be mechanically recycled or chemically converted back into monomers or basic chemicals (CE Delft, 2019; Pinlova et al., 2024), just like many fossil plastics. The same applies to other novel biobased plastics, especially given the development of chemical recycling processes that can accept a wide range of feedstocks including biobased plastics. At the moment however, the recycling infrastructure for novel biobased plastics is still very limited (not just in the automotive sector but also in packaging) mainly due to their low market volumes. Therefore, to recycle more novel biobased plastics, more recycling capacity would need to be installed. These can use the same recycling processes that are currently used for fossil plastics but would need to be set up to handle the different polymer types that novel biobased consist of[5].

The recycling infrastructure for plastics from vehicles needs to be expanded to increase the current recycling rate of 19%. This expansion should account for the main plastics used in EOL vehicles (currently and in future vehicles), regardless of whether those are fossil, drop-in biobased or novel biobased, or already recycled plastic. The availability of end-of-life recycling infrastructure is an important way of reducing the carbon footprint of plastics used in vehicles. For example, the life cycle carbon footprint results for PLA, a novel biobased plastic with currently limited recycling capacities, are highly dependent on its end-of-life treatment (Pinlova et al., 2024). To maximise end-of-life recycling rates, the recycling infrastructure should be established taking into account the polymer types used in vehicles.

Textbox 2 - Biobased or biodegradable?

Biobased and biodegradable refer to different properties of plastics[6]. The term **biobased** refers to the biological origin of a plastic – the carbon present in the plastic was captured from the atmosphere through photosynthesis in plants. This is different from fossil plastics in which the carbon comes from fossil materials previously stored underground.

Biodegradable plastics are materials that can be broken down in industrial composting installations similar to biological waste, or even in ambient conditions. There are some biobased plastics and some fossil plastic types that are biodegradable. However, many biobased plastics are not biodegradable.

During biodegradation, plastics are broken down by microbes into CO_2 and water. This does not have a direct environmental benefit. However, biodegradable plastics can be used to increase the collection of other biological waste (e.g. food and garden waste). This results in increased production of compost and retention of nutrients. For this reason, biodegradable plastics are mainly useful in applications such as food packaging where they can increase the amount of biological waste sent to composting (CE Delft, 2017).

5 For example, current sorting installations for plastics are set up to identify and sort out the most common (fossil) plastic types. This can for instance be done using near-infra red (NIR) sorting installations. To sort out new plastic types (e.g. novel biobased plastics), additional machines would be required to also identify and sort out these plastic types.

6 In addition, the term 'bioplastic' is sometimes used to refer to plastics that are either biobased and/or biodegradable. As this can be confusing, this term is avoided in this report.

Sustainable biobased plastics as an addition to recycled plastics

A key benefit of biobased plastics is their potential to reduce GHG emissions. When using biomass instead of fossil fuels as a feedstock for plastic production, no fossil carbon enters the economy, the carbon present in biobased plastic was first removed from the atmosphere through photosynthesis in plants. Because of this benefit, different biobased plastics can offer lower GHG emissions than their fossil counterparts (COWI & University of Utrecht, 2018) (Nessi et al., 2022) (CE Delft, 2023). However, there are also cases where biobased plastics have worse GHG emission performance (COWI & University of Utrecht, 2018) (Nessi et al., 2022) (CE Delft, 2023), as there are still emissions related to the agricultural stage (e.g. fertiliser and machinery use), transportation and conversion. It is therefore important to ensure that biobased plastics achieve a minimum GHG emission reduction to be eligible for government support.

The use of agricultural products (such as biobased plastics, but especially food, feed and biofuels) is also linked to expanding agricultural land. The conversion of natural land to agricultural land can cause GHG emissions (land use change) and other environmental impacts such as biodiversity loss. To avoid or minimise these impacts, policies stimulating the use of biobased plastics can be linked with strict sustainability criteria. The same is done for biofuels made from biomass in the Renewable Energy Directive. Biofuels need to meet a minimum GHG emission reduction as well as other sustainability criteria (e.g. not being produced on recently converted natural land). This topic is further discussed in Chapter 5.

If biobased plastics are produced sustainably and offer a GHG emission reduction, they can be a helpful addition to the portfolio of plastics used for vehicle manufacturers. For some vehicle parts, mechanically or chemically recycled plastics may be most suitable (e.g. from technical performance, cost, and availability perspectives); for others, biobased plastics may be a better alternative.

It can however be argued that the use of recycled plastics should be prioritised over biobased plastics, as the latter have potential negative environmental effects. In addition, there are competing uses for the agricultural land that some production routes of biobased plastics rely on. When developing policies stimulating the use of circular plastics, it can therefore be helpful to include a mechanism to steer the amounts of biobased and recycled plastic being applied.

Which biobased plastics are available for vehicles?

Table 3 provides an overview of biobased plastics/production routes that can potentially be, or are already, used in vehicles. This overview is not intended to provide an exhaustive overview of all potential biobased plastics but aims to illustrate the current situation. For each biobased plastic, we indicate which fossil plastics it could replace (as a drop-in or not), whether it is already used in the sector according to market studies, and whether mass balancing (further discussed below) is used in the production route.

The overview has been derived using two approaches:

1. A literature search for available biobased (drop-in) alternatives for the six main polymer types was conducted. The aim was to identify biobased plastics that are apparently commercially available and that could be used for the automotive sector. Scientific or lab-scale/lower TRL (Technology Readiness Level) developments of biobased alternatives are not included.

2. Market data on the current/forecast use of biobased plastic types in the automotive sector were studied (European Bioplastics, 2023; IfBB, 2022). This enabled us to identify novel biobased plastics being used in the automotive sector that are more difficult to find when looking for replacements to existing fossil plastics.

The overview includes currently commercialised (or previously commercially operated) biobased production routes for automotive applications. Note that further technological developments can increase the availability of biobased plastics or result in biobased plastics with higher biobased carbon contents[7]. Finally, in line with the scope of Table 1, only thermoplastics are included, meaning that biobased rubbers or composites using biobased fibres are excluded.

Table 3 - Examples of biobased plastics that can replace the six main currently used plastic types

Biobased plastic	Feedstock	Biobased carbon content	Replacement for	Already used in automotive?[1]	Mass balancing?
Bio-PP	Various	100%	Fossil PP (drop-in)	Yes	Yes
Bio-PE	Sugar, various	100%	Fossil PE (drop-in)	No	Depends
Bio-PET	Sugar	28%	Fossil PET (drop-in)	Yes	No
Bio-ABS	Various	Up to 80%[2]	Fossil ABS (drop-in)	No	Yes
Bio-PA	Castor oil, various	Up to 70%	Fossil PA (potential drop-in[3])	Yes	Depends
Bio-PU	Various	Unclear	Fossil PU (potential drop-in[4])	Yes	Depends
PTT	Sugar	37%	Fossil PET	Yes	No
PLA	Sugar, starch	100%	Fossil PET	Yes	No

1) According to market overviews (European Bioplastics, 2023; IfBB, 2022). Note that while bio-ABS is not present in these overviews, one producer (Trinseo) does market this biobased plastic towards automotive applications[8].
2) Bio-ABS: ABS consists of three monomers (acrylonitrile, butadiene, and styrene) which can be combined in different proportions. At present it is not clear which monomer ratios are typically used in vehicles. This means the 80% biobased carbon content may be an overestimation for use in vehicles.
3) Bio-PA: Different types of fossil PA are made by combining different monomers (such as PA6, PA6.6, PA4.6 and PA4.10). The market shares of these different types in the automotive sector are not known. Various biobased PAs (PA4.6, PA4.10, PA6.10) are available. While these can likely replace fossil PAs, it is not clear whether all fossil PAs have a biobased alternative.
4) Bio-PU: Different types of fossil PU are made by combining different monomers. The market shares of these different types in the automotive sector are not known. Various biobased monomers to produce partly biobased PU are available. While these can likely replace fossil PUs, it is not clear whether all fossil PUs have a biobased alternative.

A range of (partially) biobased plastic alternatives are available

Table 3 shows that a range of biobased plastics are available as alternatives to the six main fossil plastics. All six fossil polymer types can in principle be replaced by plastics which are at least partly biobased. In addition, PTT and PLA are novel biobased plastics that are already used (in modest amounts) in vehicles (European Bioplastics, 2022a).

7 For example, PET is made from ethylene glycol (accounting for about 30% of the weight of PET) and terephthalic acid (about 70%). Currently, only biobased ethylene glycol is produced, meaning that bio-PET is only 30% biobased. However, the production of biobased terephthalic acid is being researched.

8 www.trinseo.com/Solutions/Bioplastics-Biodegradable-Plastics/MAGNUM-CO2NET-BIO-ABS-Resins

However, not all biobased plastics in Table 3 are fully biobased. This is typically the case for copolymers, where one (or more) biobased monomer(s) is combined with one (or more) fossil monomer(s). However, in the case of mass balanced biobased polymers (where a mix of biobased and fossil feedstock is used to produce the plastic), the amount of biobased content can be varied. This is further discussed hereafter.

Note that not all biobased plastics that could potentially be used in vehicles are included in Table 3. For example, the biobased plastic PEF (polyethylene furanoate) is in development and is considered as a potential replacement for PET. However, its developers do not appear to be targeting the automotive sector at this point. Therefore PEF is not included in this overview.

Textbox 3 - Examples of use of biobased plastics in vehicles

Several car manufacturers currently use, or have previously used, biobased plastics. In this textbox we present some of the applications of biobased plastics in vehicles. Not all manufacturers make the use of biobased plastics public.[9] This overview however shows that biobased materials already find their way into vehicles.

One example of biobased plastics that have already been implemented in vehicle manufacturing is partially biobased polyamide (PA). The figures below shows a Mercedes-Benz engine cover made from EcopaXX PA4.10 (European Bioplastics, 2022a) and castor oil-based PA in fuel lines for several Fiat and Alfa Romeo models, as well as a Lancia vehicle.[10]

Image source: European Bioplastics

DURABIO™, a biobased engineering plastic is used by Renault in their speedometer, as well as the grill in a Mazda CX-5. [11] [12]

Image source: MCPP Global.

[9] Biobased materials in the motor car, part 1: automotive industry’s demands - Bio Based Press
[10] www.plasticstoday.com/sustainability/castor-oil-derived-polyamide-finds-way-into-fuel-line
[11] DURABIO™ for Renault Clio Outer Mask of Speedometer Combo (mcpp-global.com)
[12] DURABIO™ - New grade adopted for Front Grill of “Mazda CX-5” (mcpp-global.com)

Further examples are:
- biobased PVC is used for the upholstery in the Polestar 3 and 4; [13]
- PLA can be used for example for air duct parts, as shown in concept by Röchling[14]. It has also been used for car seat fabric by Mazda;[15]
- biobased polyurethane has been used in car seats for more than ten years;[16]
- biobased PET fibres are used for in a Lexus vehicle.[17]

Most fossil plastics have a direct biobased drop-in alternative, others are more complex

For PP, PE, PET and ABS, the fossil plastic can be directly replaced by a biobased plastic drop-in. These biobased plastics are chemically identical to their fossil counterparts.

The other plastics in Table 3 are not necessarily direct-drop ins. PA and PU are ‘families’ of similar but not identical polymers. At present, no information is available on which specific types of fossil PA and PU are used in vehicles (for example, the amounts of fossil PA4.6 and PA6.6). This means it is not possible to fully assess whether biobased alternatives are available for all possible variations. However, several companies are offering at least partially biobased versions of bio-PA and bio-PU. According to market research (European Bioplastics, 2022a) (IfBB, 2022), bio-PA is currently the most used biobased plastic in the automotive sector, highlighting that at least part of the fossil PA in vehicles can be replaced with biobased PA.

Finally, PTT and PLA exist of polymers that are not produced via a fossil route (sometimes called ‘novel biobased plastics’). This means they have a different chemical structure than the existing plastics and have different technical properties. Because novel biobased plastics have different technical properties than fossil plastics, a different amount of material may be required to fulfil the same function in a vehicle. For example, if the biobased material is stronger than the fossil alternative, less material may be required to produce an interior car part. Conversely, if the biobased material has a higher density, more weight may be required to produce a car part with a specific volume.

Some routes use a mass balance approach

Several biobased plastics suitable for vehicles are made using a mass balance approach. Mass balancing is a chain of custody model that can be applied when a chemical complex uses a combination of fossil feedstock and biomass feedstock as inputs. For example, a steam cracker producing basic chemicals can run on 90% fossil naphtha and 10% bio-naphtha. Steam crackers produce a wide range of outputs, including plastic precursors, non-plastic products and fuels. In this example, it is not possible to physically keep track of the biobased content; it is scattered across all outputs.

13 Materials | Polestar Global
14 Possible Applications | Röchling EN (roechling.com)
15 Biofront car seat fabric used in Mazda hybrid (innovationintextiles.com)
16 www.media.ford.com/content/fordmedia/fna/us/en/news/2017/11/02/from-seed-to-seat--how-soy-foam-proved-key-to-fords-push-to-use-.html
17 Green and Mean for 2014, the Lexus CT 200h Shakes Up the Hybrid Scene - Lexus USA Newsroom

To enable producers to market products as biobased, the mass balancing chain of custody method is used to attribute the biobased content to specific end-products. As a simplified example: instead of selling 100% of the steam cracker outputs as 10% biobased, mass balancing enables companies to sell 10% of the outputs as 100% biobased.

The main principle behind mass balancing is that for each kg of biogenic carbon attributed to a product, one kg of fossil carbon has been replaced. However, since the outputs physically only contain 10% biobased content, organisations such as Bioplastics Europe promote the term ‘bio-attributed’ to indicate that the use of renewable feedstock has been ascribed using mass balance approach.

The mass balance approach enables the chemical sector to gradually introduce biobased content into their complex production lines. The biobased content can be attributed to those specific end-products where it offers the highest added value. This can make it economically feasible to partially start using biomass as a feedstock when it is not yet economically attractive to switch over 100% to biomass.

However, it should be noted that different versions of mass balancing exist, which offer different amounts of freedom to producers. For example, ‘free allocation’ mass balancing allows producers to attribute all biobased content going into a steam cracker to specific end-products. This includes the biobased content that is burnt in the steam cracking process or biobased content that is physically converted into fuels.

Conversely, ‘fuels exempt’ mass balancing only allows producers to attribute the biobased content that ends up in plastics or other physical, non-fuel products to specific end-products. This means that the biobased content that is not physically converted into products (and is thus removed from the economy) cannot be attributed to end-products.

For the currently marketed biobased plastics that use mass balancing, it is not always clear which mass balance approach has been used.

The same mass balance approaches that are used for biobased content can be used for recycled content in plastics. Chemical recycling, particularly pyrolysis, faces the same issue as some biobased plastic routes: it is not yet economically possible to run a steam cracker fully on pyrolysis oil, but it can be fed into the process in small amounts.

4 Substitution potential in vehicles

We now discuss the potential magnitude and effects of a substitution of fossil plastics with biobased plastics in vehicles. We first consider the technical substitution potential, i.e. the maximum replacement currently possible, assuming no limitations on e.g. feedstock availability, production capacity or the use of mass balancing. We then focus on a substitution rate of 5 to 10% and discuss the effects of such a target in the context of the expected production capacity for biobased plastics and the biofuel market.

Technical substitution potential: up to 70%?

To determine the technical substitution potential, we consider the six main polymers currently used in vehicles (Table 1) and the drop-in alternatives (Table 3). Table 4 shows the share of each polymer type and the biobased potential substitution rates, using the highest biobased content values found in literature.

This approach leads to a technical substitution potential of 70% of which more than 50% (PP, PE and PET) are drop-in alternatives. On the one hand, this could be an overestimation as we did not consider the possible chemical variations in ABS/SAN, PA, and PU. It is possible that high biobased content rates can be achieved with PA4.10, but that vehicles are mainly built using PA6.6, for example. On the other hand, this calculation only considers drop-in biobased plastics for the 6 main polymer types, while higher overall substitution rates can be achieved when novel biobased plastics and the ‘other plastics’ are considered as well.

Table 4 - Technical substitution potential of biobased plastics

Plastic	Share in future EU vehicles[a]	Biobased substitution potential	Rationale
PP	37-40%	100%	Drop-in.
PU	10-15%	35%	Very dependent on type of PU variant whether (and to what extent) biobased polyols can be used. Biobased MDI or TDI might be possible based on mass balancing and accounts for roughly 35% of weight.
PA	8-12%	70%	Dependent on type of PA whether biobased alternative is available. Maximum biobased content is currently 70%.
PE	8-15%	100%	Drop-in.
ABS/ SAN	5-7%	80%	ABS with up to 80% biobased content (based on mass balancing) is currently offered. The biobased content seems to depend on type of ABS/SAN used.
PET	8-10%	30%	30% of biobased feedstock (ethylene glycol) can be biobased.
Others	12-13%	0%	Not studied in this report, so assumed no biobased substitution.
Sum	**100%**	**67-71%**	

a) Based on cars as shown in Table 1. Range shows difference between either internal combustion engine vehicles or battery electric vehicles.

Feasible, short-term substitution potential: 5-10%

While the technical substitution potential of biobased plastics is high, other factors should be considered as well, including the availability of biomass, production capacity for biobased plastics and the economic consequences of a substitution target. For a shorter-term target, e.g. for 2030, we consider a substitution rate of 5% to 10% feasible.

Substitutions in this range can plausibly be achieved for vehicles in the near future while being large enough to generate a substantial effect. In addition, a substitution of 5 to 10% in the European vehicles market fits within the (current expectations for) global production capacity of biobased plastics and is unlikely to disturb the European market for renewable fuels. These arguments are further discussed below. Over time, the feasible substitution potential can increase.

A substitution of 5 to 10% corresponds with a biobased plastic demand of 111-222 ktonne per year. This target can be met in different ways, considering the available drop-in biobased plastics and the composition of the average vehicle (Table 4). One option would be to replace part of the fossil-based PP with biobased PP. As more than 35% of plastic in vehicles is PP, a target of 5-10% would be met by replacing less than one third of the PP. A route without mass balancing is also possible, for example by replacing fossil PE by biobased PE and part of the fossil PA by biobased PA. Other combinations are of course also possible.

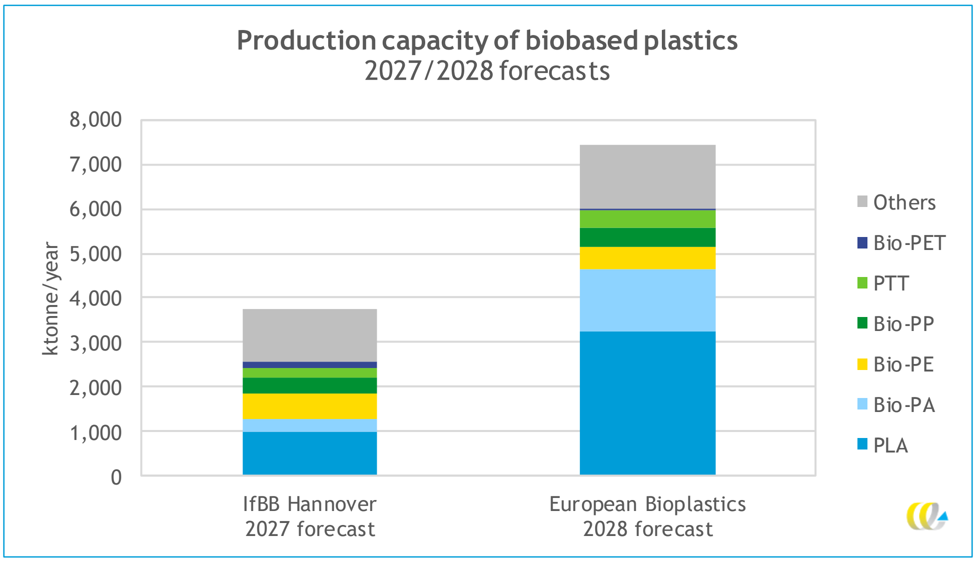
Sufficient biobased plastics production capacity is available for 5-10% substitution

The current global yearly production of biobased plastics is around 2000 ktonnes (European Bioplastics, 2023). The future availability of biobased plastics is more uncertain[18], with estimations of global production of biobased plastics capabilities of 3,753 and 7,432 ktonne/year in 2027/2028, as shown in Figure 3. A total demand of 222 ktonnes biobased plastics would represent a 3-6% share of the expected global production of biobased plastics by 2027/2028. A substitution rate of 5-10% would therefore make European vehicles a relatively large user of (expected) global biobased plastic capacity.

However, it should be noted that the production capacity for biobased plastics can be steered by policies for circular plastics. Policies promoting the use of biobased plastics can lead to a global increase in their production capacity. Such policies can also decrease the uncertainty in the demand for biobased plastics industry and increase future availability of biobased plastics that can be used in vehicles.

[18] Some uncertain aspects can be noted here:
- The sources may include partially biobased plastics, as well as biodegradable fossil plastics.
- Of the biobased plastics included in the 'Others' category, not all may be fit for use in vehicles.
- It is not clear whether routes based on mass balancing are included. With mass balancing, biobased content can be 'swapped' from one plastic to another without the need to build new production facilities. This increases the uncertainty of the forecast capacity for specific polymers types.

Figure 3 - Forecast production capacity of biobased plastics in 2027/2028, ktonne/year



Source: IfBB (2022) and European Bioplastics (2023).

At 10% substitution, the market for biobased plastics in vehicles is small compared to the ethanol biofuel market

Various biobased plastics can be produced from the same biomass feedstocks that are used to produce biofuels. For example, sugar can be used to produce bioethanol, which can either be blended into gasoline as a biofuel, or be converted into bio-ethylene and then bio-PE.

The current market for biofuels is very large when compared to the potential demand for biobased plastics that would be introduced by a 5-10% substitution target in vehicles. The expected yearly demand for bioethanol for the European fuel market is 6,000 ktonne per year until 2028 (EC, 2023a). A 10% target for biobased plastics in vehicles would require 222 ktonne of biobased plastic, or less than 4% of the current use of bioethanol fuel.

Textbox 4 - Biomass demand in perspective

Currently the use of biomass for biobased plastics is very low compared to feed, food and energy. Biobased plastics accounted for an estimated 0.015% of agricultural land in 2022, compared to 4% for biofuels (European bioplastics, 2022b). The competition for agricultural land is expected to increase in the future, also in applications outside of biobased plastics. While there is a large variability in results, studies show that a mismatch between supply and demand for biomass is expected to grow within the EU (EEA, 2023). The demand for biobased plastics therefore competes with other uses for biomass.

However, the use of biomass for biobased materials (such as biobased plastics) is preferable over the use of biomass for energy. Following the principles of circularity, material applications should be prioritised over energy applications, since energy applications effectively lose materials and hamper the circular economy (Vural Gursel et al., 2022). Nevertheless, policies promoting use of biomass is currently skewed towards using biomass for energy over use of biomass for materials (SER, 2020). This increases biomass prices for use in biobased plastics and results in a non-level playing field between biofuels and biobased plastics. The question of scarcity of biomass for biobased plastics is therefore also a matter of prioritisation.

5 GHG emission reduction potential

This section considers the greenhouse gas (GHG) emission reduction potential of a biobased plastics target for vehicles. While biobased plastics can reduce GHG emissions compared to fossil plastics, some life cycle assessment (LCA) analyses conclude that specific biobased plastics have higher GHG emissions than their fossil counterparts. Stimulating these negative examples of biobased plastics is not the aim of policy makers.

In this chapter we reflect on whether biobased plastics (can) have a lower carbon footprint than their fossil counterparts and explain the variability in LCA results. For this we reviewed claimed GHG emissions by producers and the methodology used. Then we present a methodology to calculate GHG emission reductions for biobased plastics. Finally we show emission reductions based on examples of scenarios with different targets for biobased plastics and minimum GHG emission reduction targets.
The main takeaway of this analysis is that GHG emissions can be reduced if a uniform calculation method of GHG emission reductions for biobased plastics is introduced. Biobased plastics that count towards the circular plastics target should meet a minimum GHG emission reduction target can be set. If, for example, a minimum GHG emission reduction of 1 kg CO_2-eq./kg biobased plastic is combined with a 10% biobased plastic target, yearly GHG emission reductions of more than 200 ktonne CO_2-eq. are possible.

Claimed GHG emission reductions should be validated

Many producers of biobased plastics communicate the estimated GHG emission reductions of biobased plastics in comparison with fossil plastics, based on LCA studies. The variety in reported GHG emission reductions for the biobased plastics listed in Table 3 is large. Producers claim reductions up to 4.6 kg CO_2-eq. saved per kg biobased plastic used. However, these values published by producers should not be taken at face value.
Most producers only publish (preliminary) LCA results with no elaboration on methodological choices. In addition, prior research (e.g. CE Delft (2023) and Nessi et al. (2022)) has shown that GHG emission estimates ('carbon footprints') of different biobased plastics can vary substantially.

Results in LCA studies of the same biobased plastics type can vary due to:
- the value chain studied (i.e. 'real' differences);
- methodological factors.

Key drivers in the first category are the biomass feedstock used, associated land use change, useful application of coproducts and energy use of conversion processes. In the second category, important methodological aspects that affect the GHG emission results of biobased plastics are for instance:
- geographical, temporal and technological scope;
- system boundaries, e.g. which processes are taken into account and how;
- treatment of co-products (e.g. allocation or environmental credits based on system expansion);
- treatment of biogenic carbon;
- in the case of novel biobased plastics: accounting for differences in functionality compared to petrochemical reference;
- choice in impact assessment method;
- choice of background datasets.

In addition, note that for biobased plastics where mass balancing is used, the GHG emissions of a product can be modified by the producer (to some extent) by increasing/decreasing the amount of allocated biobased content.

The large influence of methodological differences, combined with the lack of transparency of current LCA results published by producers, indicates the need for uniform methodology when evaluating biobased plastics and comparing environmental performance to fossil-based counterparts. At the end of this chapter, we further discuss a uniform calculation method.

A uniform calculation method for GHG emission reductions

As an important goal of using biobased plastics is to achieve GHG reductions, it is vital that only plastics with GHG emission reductions are allowed to count towards a target. It is therefore crucial that a methodology will be prescribed for comparing GHG emissions of biobased plastics to their fossil counterparts.

We propose to use a calculation method with sustainability criteria similar to the European Union's Renewable Energy Directive (RED II[19]) to determine GHG emissions. A JRC study (Nessi et al., 2022) showed that without sustainability criteria the GHG emissions of biobased plastics can be higher than their fossil counterpart in several applications. With sustainability criteria, multiple biobased plastics can have a lower carbon footprint than their fossil counterpart (CE Delft, 2023). Another goal of including sustainability criteria is to limit potential negative effects of using biomass on aspects other than climate change.

Our proposal is to develop a calculation method for GHG emissions reduction and combine this with biomass sustainability criteria, similar to the approach for biofuels in the RED. The calculation method is used to determine the GHG emissions of a biobased plastic. These are compared to an appropriate fossil plastic reference. Only biobased plastics that meet a minimum GHG emission reduction using the calculation method and compared to the reference can count towards the target for biobased plastics in vehicles.

By aligning with the RED rules for biofuels as closely as possible, a level playing field for the use of biomass is created. This will for instance ensure that a biomass source that is not allowed to be used for biofuels based on sustainability concerns can be used for biobased plastics.

Two key aspects of the GHG emission method should be highlighted here:
1. **Fossil reference values**. To compare the GHG emission reduction of a biobased plastic, a fossil plastic reference (and corresponding GHG emissions) should be defined. The carbon footprints of fossil plastics vary strongly, so reference products should be specific for each type of biobased plastic. For drop-in biobased plastics, the fossil reference should be the fossil counterpart (i.e. bio-PP should be compared to fossil PP. For novel biobased plastics, a reference GHG emission should be based on the (mix of) fossil plastics that will be replaced by the biobased plastics. This should be established in dialogue with the industry.

[19] RED II refers to EU Directive 2018/2001/EU, which is currently in force. This is a revised version of the original RED (Directive 2009/28/EC).

2. **System boundaries**. We propose to calculate the GHG emissions from cradle-to-gate, so excluding end-of-life. This avoids the need for complex modelling of EOL scenarios, involving the estimation of expected shares of recycling, incineration or landfilling. This helps to keep the calculation method relatively simple, but it is important to consider whether this approach results in inaccuracies. Since many available biobased plastics are direct drop-ins, the EOL GHG emissions will be identical to their fossil counterparts. For novel biobased plastics, the EOL recycling infrastructure may currently be less developed than that of drop-in biobased plastics. If these recycling systems are developed, which will be stimulated by the mandatory target for the use of recycled plastics, the EOL GHG emissions will also be comparable.

More details on the proposed carbon footprint calculation method can be found in Annex A, where we compare our proposal to the JRC methodology for calculation of biobased plastic impacts (Nessi et al., 2022) and the RED II and explain our reasoning.

Yearly GHG emission reductions over 200 ktonne CO_2-eq. are possible, depending on substitution rate and required GHG emission reductions

In previous work, we found that a GHG emission reduction target of 1 kg CO_2-eq/kg plastic reduction was achievable for different biobased plastic types, including bio-PE and bio-PP (CE Delft, 2023). While this target ensures that GHG emissions go down, it still allows different pathways and biomass feedstocks for the production of biobased plastics. As in the Renewable Energy Directive (RED II) for renewable energy and biofuels, the reduction would be determined using a uniform calculation method (as described above) and the target can be increased over time. A 1 kg CO_2-eq reduction translates to a reduction of 20 to 63% depending on the plastic type and waste treatment scenario (see Table 7 of CE Delft (2023)).

If we assume a 10% replacement of plastics in vehicles and a minimum GHG emission reduction of 1 kg CO_2-eq./kg biobased plastic, the yearly reduction of GHG emissions across the EU would be 222 ktonne CO_2-eq. This is shown as Example 1 in Table 5 below. Alternatively, a higher minimum GHG emission reduction target of 1.5 kg CO_2-eq./kg biobased plastic would result in a reduction of 335 ktonne CO_2-eq./year. Finally, a smaller biobased plastic target of 5%, combined with a 1.5 kg CO_2-eq./kg GHG emission reduction requirement would result in a total reduction of 167 ktonne CO_2-eq./year.

Note that the GHG emission reductions could be larger in practice, since the 1.0 and 1.5 kg CO_2-eq./kg reductions are minimum requirements.

Table 5 – GHG emission reductions for scenarios on biobased plastic targets and GHG emission reductions

	Example 1	Example 2	Example 3	Notes
Plastics use in vehicles (EU) ktonne/year	2,224	2,224	2,224	See Table 2
Target for biobased plastics % of plastics used in vehicles	10%	10%	5%	Feasible substitution potentials, see Chapter 3
Minimum GHG emission reduction kg CO_2-eq./kg biobased	1.0	1.5	1.5	
Minimum annual GHG emission reduction ktonne CO_2 eq./year	222	334	167	

6 Conclusions and policy considerations

This study assesses whether biobased plastics can be used to substitute a substantial (i.e. 5 to 10%) share of fossil plastics currently used in vehicles and provides a high-level estimate of the potential GHG emissions of such a substitution. The key findings are:
- various biobased plastics are already used by European vehicle manufacturers, including bio-PA, PTT and PLA (European Bioplastics, 2023);
- there are suitable biobased plastic options available to substitute the bulk of the fossil plastics currently used in vehicles;
- biobased plastics can reduce GHG emissions compared to fossil plastics, but a uniform calculation method and sustainability criteria are needed;
- substantial substitution rates are possible (5% to 10%) are possible in the short-term, based on expected biobased plastic production capacity;
- setting up a policy system with targets for the use of both recycled plastics and/or biobased plastics in vehicles now will enable the EU to move towards much higher circular plastic content targets in vehicles by 2040 or 2050.

In the development of a biobased content target for vehicles, several aspects need to be considered by policymakers.

Whether and how to combine targets for recycled and biobased plastics in vehicles

A mandatory minimum target of 25% for the use of circular plastics is being considered by the European Commission. In the context of this discussion, different policy options including and excluding biobased plastics can be considered:
1. **Target for recycled plastic only**: Manufacturers are obligated to use at least 25% recycled plastic in all vehicles.
2. **Separate targets for recycled plastic and biobased plastic**: Manufacturers are obligated to use (for example) at least 25% recycled plastic and 5% biobased plastic in all vehicles.
3. **Combined target**: Manufacturers are obligated to use at least 25% recycled and/or biobased plastic in all vehicles.
4. **Combined target with a cap on biobased**: Manufacturers are obligated to use at least 25% recycled and/or biobased plastic in all vehicles. Biobased plastics can account for at most (for example) 10% of the target.

Table 6 provides an overview of these options and their potential effects.

Table 6 - Four policy variations for a mandatory target for recycled and/or biobased plastics in vehicles

1.	**Target for recycled plastic only** Manufacturers are obligated to use at least 25% recycled plastic in all vehicles
–	No mandatory use of biobased plastic for the target, limiting technological options for vehicle manufacturers.
–	Height of target can eventually be limited by availability of recycled plastics/available waste plastic.
–	Strongest stimulus for recycled plastic.
2.	**Separate targets for recycled plastic and biobased plastic** Manufacturers are obligated to use (for example) at least 25% recycled plastic and 5% biobased plastic in all vehicles
–	Two separate targets can increase complexity for vehicle manufacturers, as they cannot choose to exchange biobased for recycled plastics and vice versa.
–	More level playing field for biomass applications (both biobased plastics and biofuels are stimulated).
–	Very predictable future demand for recycled plastics and biobased plastics in the automotive sector.
3.	**Combined target** Manufacturers are obligated to use at least 25% recycled and/or biobased plastic in all vehicles
–	Highest flexibility for manufacturers; manufacturers can deal with price shocks of materials more easily by substituting biobased for recyclate or vice versa.
–	More level playing field for recycled and biobased plastics in automotive sector, and more level playing field for biomass applications (both biobased plastics and biofuels are stimulated).
–	Possibility that more biobased plastics than recycled plastics are used, thereby limiting the effect of the obligation on EOL plastics collection, sorting and recycling.
–	Future demand for recycled and biobased plastics is difficult to predict, as manufacturers can switch between (e.g.) recycled PP and bio-PP based on market prices.
4.	**Combined target with cap on biobased** Manufacturers are obligated to use at least 25% recycled and/or biobased plastic in all vehicles. Biobased plastics can account for at most (for example) 10% of the target.
–	High flexibility for manufacturers; manufacturers can deal with price shocks of materials more easily by substituting biobased for recyclate or vice versa.
–	More level playing field for recycled and biobased plastics in automotive sector, and more level playing field for biomass applications (both biobased plastics and biofuels are stimulated).
–	Policymakers can control amount of biobased plastics used in vehicles and ensure that plastic recycling is prioritised.
–	Future demand for recycled and biobased plastics is difficult to predict, as manufacturers can switch between (e.g.) recycled PP and bio-PP based on market prices.

From Table 6 it is apparent that different policy designs have different effects and trade-offs. If biobased plastics are included, vehicle manufacturers have more flexibility to choose the most appropriate/cost-effective materials. This can mean the targets can be met at a lower cost to manufacturers and price shocks can be more easily absorbed.

For policymakers, a combined approach creates a more level playing field for circular plastic options. It avoids the need to determine which individual targets for biobased content and recycled content are feasible. An additional advantage is that the transition to circular plastics becomes less reliant on the availability of waste plastics for recycling.

Overall, by including biobased plastics, the circular plastic target becomes easier to achieve for vehicle producers. Over time, the target for circular plastics in vehicles could be increased faster compared to a situation in which only recycled plastics are used. However, increased flexibility for manufacturers can make it more difficult to predict the future demand of recycled and biobased plastics. This creates uncertainty for investors deciding whether to build new waste plastic sorting and recycling facilities or companies considering adding new biobased plastic production lines.
Another consideration is that a combined target can lead to a situation in which large amounts of biobased plastic are used in vehicles, while the amount of recycled plastic in vehicles is limited. A cap on the amount of biobased plastic that can count towards the circular plastics target can prevent this.

A final attention point is that plastics can be both recycled and biobased. For example, products made from used cooking oil can be considered both. It is important to clearly distinguish these categories and/or to avoid double counting the contribution of these materials to the targets.

Choice on whether mass balancing (and which variations) should be allowed

As discussed in Chapter 3, some currently available biobased plastics use mass balancing, and different mass balance approaches are possible. This issue is not unique to biobased plastics; the same approaches are being discussed for recycled plastics.

Policymakers need to decide whether to allow the use of mass balanced plastics in meeting the recycled/biobased content targets. From the perspective of a level playing field, the same mass balancing rules should apply to biobased and recycled plastics.

Establishing a uniform GHG emission reduction methodology and other sustainability criteria

The estimated GHG emission reduction of biobased plastics depends not just on the specific supply chain, but also on the LCA methodology applied. In addition, various studies show that biobased plastics can, in some cases, lead to higher GHG emissions than fossil plastics. Therefore, biobased plastics should meet a minimum GHG emission reduction to count towards a biobased content target for vehicles. In addition, GHG emission reductions should be determined using a uniform calculation method.

The biomass sources used for biobased plastics are similar to those used for biofuels or can be produced on the same agricultural land. To level the playing field for different biomass applications, similar calculation methods should be used for both. Since the GHG emission reduction calculation method for biofuels has been established in the EU’s RED II, a very similar method can be used for biobased plastics. Chapter 5 summarises what such a calculation method could look like, and how it compares to the RED II calculations for biofuels.

As a starting point, a minimum GHG emission reduction of 1 kg CO_2-eq./kg biobased plastic can be used. While this target ensures that GHG emissions go down, it still allows different pathways and biomass feedstocks for the production of biobased plastics.

Beyond GHG emissions, other negative effects of an increase in biomass demand for biobased plastics in vehicles, such as biodiversity loss, should be avoided. For a level playing field, the same biomass sustainability criteria that are used for biofuels under RED II can be used for biobased plastics.

Recyclability of biobased plastics

The recycling rates of plastics from EOL vehicles can be improved, and this will be stimulated by a mandatory target for the use of recycled plastic in vehicles. Biobased plastics can be recycled with the same technologies as fossil plastics. When developing the recycling infrastructure for plastics from EOL vehicles, it is important to consider which polymer types are used in vehicles (regardless of whether they are fossil, recycled or biobased).

Preparing for future expansion of circular plastics in vehicles

The present discussions at the EU level focus primarily on recycling and a 25% target for recycled plastics in vehicles. While a 25% target may be achievable with just recycled plastics, it is important to prepare for future increases of the target. These will be increasingly difficult to achieve with only recycled plastics (see discussion at the end of Chapter 2).

Including biobased plastics[20] in the target now will ensure the policy is more future-proof. Even if a cap is used to ensure that only a small amount of biobased plastic is used in vehicles, it would send a strong signal that the EU is looking beyond just one technological solution to avoid fossil plastics in vehicles. This will prepare vehicle manufacturers, plastic producers and recyclers for a future situation in which a variety of circular strategies will be needed to ultimately reach 100% non-fossil plastics in vehicles.

If a combined target is implemented (with or without a cap on biobased), the share of biobased plastics in vehicles can be monitored over time. This will make it clearer to what extent biobased plastics are competitive with recycled plastics, and whether they both have particular strengths and weaknesses when used in vehicles. In line with the RED for biofuels, the target(s) for using recycled and/or biobased plastics can be increased over time and the minimum GHG emission reductions can be increased as well. While the biobased plastics market may initially need some time to get established, timely communication on increased biobased plastic targets will increase the capacity of producers.

[20] Note that plastics produced from captured carbon can also be included to ensure a more level playing field for all circular plastic options.

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A Comparison calculation GHG emissions with JRC and RED II

Table 7 - Overview of main characteristics of carbon footprint calculations, adjusted from (CE Delft, 2023)

	JRC	RED II [21]	Our proposal	Explanation
Product	Plastic	Renewable energy	Plastic	
Functional unit	The function of the studied product	The energy content of the studied product	Amount of plastic	Using the amount of plastic avoids determination of function for every application.
Comparison with fossil alternative	Based on the function	Based on the energy content	For drop-in: Based on the mass. For others: Based on the mass and corrected with replacement factor	Using the mass of plastics gives a fair comparison between biobased and fossil plastics for drop-ins. For others, mass of biobased plastics can differ from fossil plastics, so correction factors should be prescribed.
System boundaries	Cradle-to-grave (includes EOL based on scenario)	Cradle-to-grave (includes emissions from use of fuel)	Cradle-to-gate (no EOL)	Evaluation at cradle-to-gate level avoids the need for (complex) EOL scenarios. Drop-in biobased plastics have the same EOL scenario as their fossil counterpart, so here this choice does not change the results. For novel biobased plastics EOL options are currently limited, this can lead to different outcomes compared to including EOL in system boundaries.
Reduction compared to fossil alternative	N/a	Percentage (depending on energy type and start of operations)	Absolute amount (e.g. 1 kg CO_2-eq./kg plastic)	Using an absolute amount creates a level playing field between different biobased plastics and removes dependency on system boundaries.
Biogenic CO_2	Biogenic CO_2 excluded	Biogenic CO_2 excluded	Biogenic CO_2 included	As we recommend comparing at cradle-to-gate level, including biogenic carbon uptake in the calculation gives a fair comparison. Within the cradle-to-gate scope, biobased plastics contain biogenic carbon captured from the atmosphere. When extending calculations from cradle-to-grave, all emissions including biogenic CO_2 should be counted for a fair comparison with fossil plastics.

[21] Only the part of RED II that is focussed on biofuels, bioliquids and biomass fuels is included in this overview.

	JRC	RED II [22]	Our proposal	Explanation
Allocation	Allocation avoided if possible by subdivision or system expansion, after this allocation based on physical property preferred	Energy allocation	Energy allocation	Using energy allocation gives the same results as the RED for intermediate products such as ethanol.
Direct LUC	dLUC included	dLUC included	dLUC incluced	Direct land use change is an important potential contributor to GHG emissions of biobased products, so this should be included.
Indirect LUC	iLUC excluded from calculation, but reported	iLUC excluded (high iLUC crops not allowed)	Multiple options, to be determined by policy makers	If crops with iLUC are excluded by sustainability criteria, inclusion in calculation not necessary.
Impact categories	GHG + other PEF categories	GHG	GHG	Focusing on GHG emissions only fits with policies for climate change reduction and aligns with RED.

[22] Only the part of RED II that is focussed on biofuels, bioliquids and biomass fuels is included in this overview.