planet A
VENTURES

LIFE CYCLE ASSESSMENT

traceless

As the first European venture capital fund, Planet A relies on its own scientific team to assess the environmental and climate impact of an innovation. Prior to an investment, a life cycle assessment, like this one, is conducted and integral part of the investment decision. All assessments as well as the methodology is published for maximum transparency.

Terminology and abbreviations

bioPE	Bio-based polyethylene
bioPP	Bio-based polypropylene
BR	Brazil
CED_f	Cumulative fossil energy demand
CO_2-eq.	Carbon dioxide equivalents
DDGS	Dried distiller’s grains with solubles
EOL	End of Life
EU	European Union
Functional unit	Quantified performance of a product system for use as a reference unit
GHG	Greenhouse gas
HDPE	High-density polyethylene
HVO	Hydrotreated vegetable oil
LCA	Life cycle assessment
LDPE	Low-density polyethylene
MSW	Municipal solid waste
PBAT	polybutyrate adipate-terephthalate
PET	Polyethylene terephthalate
PLA	Polylactic acid
PP	Polypropylene
Sb-eq.	Antimony equivalents
WSI	Water Stress Index

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1. About traceless

traceless developed a novel approach to provide bio-based substitutes for plastic. traceless' material is fully biodegradable within short time frames under natural conditions. The material can replace conventional plastics in single use products such as low and high-density polyethylene (LDPE and HDPE), polypropylene (PP) polyethylene terephthalate (PET) in packaging applications. A targeted market is (food) packaging.

2. About this study

This is a summary report of a detailed life cycle assessment (LCA) study evaluating the potential environmental impacts of traceless and other alternatives to conventional plastics. **The main focus lies on the environmental impacts as a result of the provision of traceless material to the market at large scale. In addition, changes in environmental impacts resulting from an increase in production of a selection of other alternatives to conventional plastics is assessed.** Aside from **traceless material, bio-based bioPE, bioPP, PLA and PBAT are assessed**. The demand for alternatives to conventional plastics is growing rapidly. Therefore, it is unlikely that the alternative materials substitute each other. Most likely, all of these materials will displace conventional plastics.

A consequential LCA approach is applied to evaluate the change in environmental impacts arising from the substitution of conventional plastics. The approach evaluates marginal changes within the economy as a consequence of a change in the market structure (e.g. entry of a new market participant, such as traceless), production modalities, demands as well as political, consumer or any other decision affecting the former aspects (Ekvall et al. 2016). Compared to other methods of impact assessments (e.g. using the GHG protocol method), this consequential approach goes beyond the company perspective and offers a more holistic picture of the overall environmental net change in impact[1]. In contrast, a Cradle-to-Grave approach, the evaluation only includes the full life cycle from raw material over production to disposal. Both approaches have different applications and different questions can be answered. The applied consequential LCA approach allows the estimation of changes in environmental impacts arising from a change in the market, such as the market entry or scaling of a company. In contrast, the attributional LCA approach, such as applied in GHG protocols and Cradle-to-Gate/Grave analyses focuses on environmental hot-spots within a supply chain. Hence, both approaches are used for different purposes and answer fundamentally different questions regarding the impact of a company or product.

2.1. Functional unit

The functional unit of this study is defined as **1 kg of traceless material replacing conventional plastics**. The focus of this study is the European market. In addition, a number of other alternative products are assessed.

2.2. Assessed indicators

In total, five LCA indicators were evaluated:

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[1] For more information, the reader is referred to https://consequential-lca.org/clca/why-and-when/ and other literature on attributional and consequential LCA.

1. climate change/GHG emissions (Intergovernmental Panel on Climate Change (IPCC) 2014),
2. abiotic resource depletion (CML 2001 v. 4.7 2016 (CML - Department of Industrial Ecology 2016),
3. cumulative fossil energy demand (CED_f) (Verein Deutscher Ingenieure (VDI) (ed.) 2012),
4. water demand (WSI) (Pfister, Koehler, and Hellweg 2009),
5. land demand

2.3. System boundaries, data and key assumptions

In the following sections, the system boundaries, data sources and key assumptions of all materials assessed are described. All data sources are mentioned. The reader is referred to the mentioned sources for detailed information on the assessed processes and the life cycle data used. All sources mentioned provide the used data (except for traceless materials).

2.3.1. traceless material

The evaluation comprises the full life-cycle of traceless products as well as other effects arising from traceless' activities (Figure 1). traceless uses agricultural industry residues, namely a production sidestream of the food industry[2]. The process yielding the traceless' feedstock (agricultural industry residues) primarily provides food products. The economic viability of the process generating traceless' feedstock is determined by its primary products. At present, the secondary product of this process, used as feedstock by traceless, is used as animal feed in the feed industry.

If traceless sources this feedstock, the corresponding amount of the feedstock material is not available as animal feed any longer. Thus, alternative supply for the feed market will be needed (assuming unaffected demands for animal feed).

The production of the feedstock itself is excluded from this evaluation because there won't be any additional production of this feedstock material due to traceless' operations (because it is only a low-value side-stream of the primary food production process), nor will there be any changes in production modalities that can be accounted to traceless' operation. The only change triggered by traceless' production is an increase in feed supply by other means to displace the feedstock now used by traceless' on the feed market.

Most likely products provided by traceless will displace existing, fossil-based packaging materials. Technically, a substitution of recycled material is also possible. In such a case, the surplus in recycled plastic is likely to reduce the overall demand for virgin plastic, too. Therefore, a significant overall displacement of recycled material through traceless material is not expected to happen, and this scenario has not been evaluated. As traceless materials are 100% biodegradable within short time-frames, traceless products will also displace the existing end-of-life (EOL) of existing packaging materials (a combination of recycling, incineration, landfilling and leakage into the environment). Traceless is fully biodegradable within short timeframes. Hence, the EOL of traceless

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[2] The feedstock is known to Planet A and all calculations are based on feedstock data. Due to confidentiality reasons, the feedstock cannot be disclosed in a public available report. The detailed LCA report contains all information and background data.

assessed in this study comprises composting and incineration. Likewise, recyclable plastics are treated by recycling, landfilling and incineration. In this study, the substitution of low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyethylene (PP) and polyethylene terephthalate (PET) was assessed.

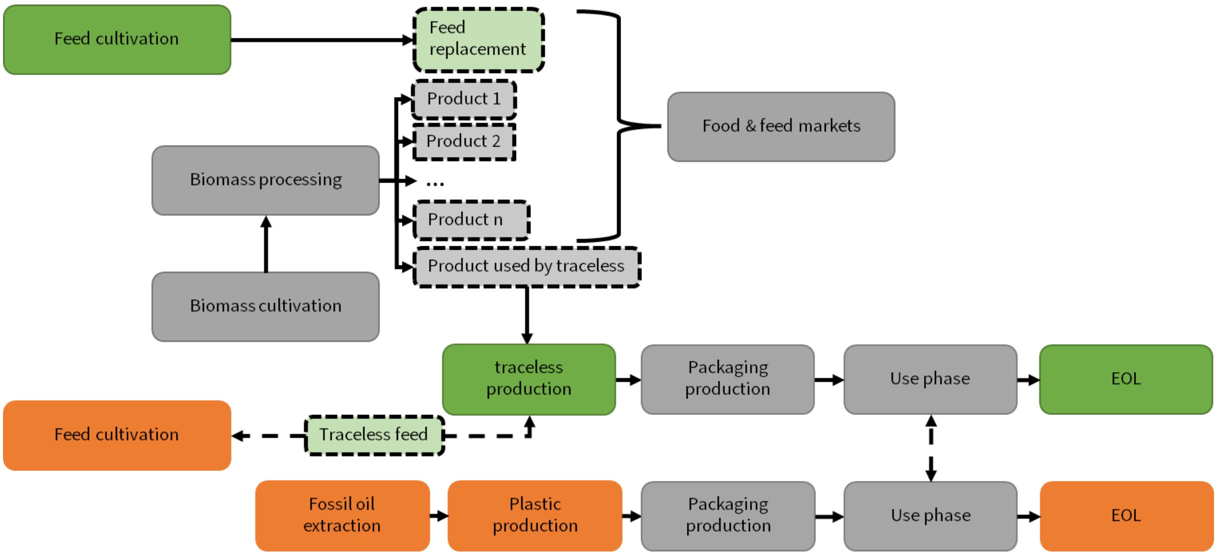

Figure 1 *Depiction of system boundaries. The assessed system comprises the life cycle of products made of traceless material and potential displacements of conventional plastic products. Green processes will commence/increase operation due to traceless; orange processes will cease to operate or reduce their production. Abbr.: EOL – End-of-life.*

Life cycle inventory (LCI) data was supplied by traceless for a pilot plant and full-scale production. In this study, full scale production data is applied.[3] traceless uses thermal energy which is supplied by a biomass power plant traceless supplies part of its side-stream (*traceless feed*) to the biomass power plant to produce heat. Electricity is drawn from the grid, but purely from renewable sources (certified electricity from renewable sources). traceless acquires feedstock from suppliers in Germany and France. Food and feed is mainly transported by inland barge and truck (BVU Beratergruppe Verkehr + Umwelt GmbH 2016). Based on this information and on information supplied by traceless, 50% of transport distances are covered by inland barge and 50% by truck. For all stages of the products' life-cycles, the LCA considers energy consumption, energy sources, water use, wastewater, auxiliary materials (such as consumables used in production and additives), waste etc. traceless' production processes were modeled in a techno-economic assessment. The model was used to plan and design the industrial-scale facility. traceless material can substitute LDPE, HDPE, PP and PET. In this study, the virgin production of PP, PE and PET is considered. traceless material can be used in many applications and it is assumed that traceless material can be processed within existing production processes without any significant changes in process energy or material requirements. All background processes and substituted products were modeled using the ecoinvent 3.8 database (consequential system model) (Wernet et al. 2016).

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[3] The LCI of traceless is confidential and not included in this public report.

2.3.2. bioPP

NESTE produces hydrotreated vegetable oil (HVO) from used and virgin vegetable oils, a drop-in fuel to substitute conventional fossil diesel fuel. The main product (in terms of economics and quantities) of NESTE's NEXBTL process is HVO. In addition to HVO, the process produces naphtha. Naphtha can be further processed by hydrocracking to produce ethylene, propylene and small quantities of other hydrocarbons. In subsequents steps, ethylene and propylene can be converted to PE and PP, respectively, via polymerisation processes. Therefore, the supply of bioPP and bioPE via this route depends on the production quantities of HVO. NESTE announced to substantially increase the production capacities of HVO (Link), resulting in an increase in bio-based naphtha production (Link 1, Link 2). Since the production of naphtha is inevitably coupled with the production of HVO, bioPP will be supplied to the market in any case due to the increase in HVO production capacities. Since the demand for plastic alternatives is rapidly increasing, the market readily absorbs the supply of bioPP. In this study, it is assumed that the demand for bioPP only results in the additional efforts to produce bioPP from (bio-)propylene, since propylene and all other side-products of the NEXBTL process are anyways produced by the NEXBTL process (Figure 2). The inventory of the bioPP synthesis was taken from (Moretti, Junginger, and Shen 2020). The scientific study is a first-hand assessment using primary data of NEXBTL and bioPP production processes.

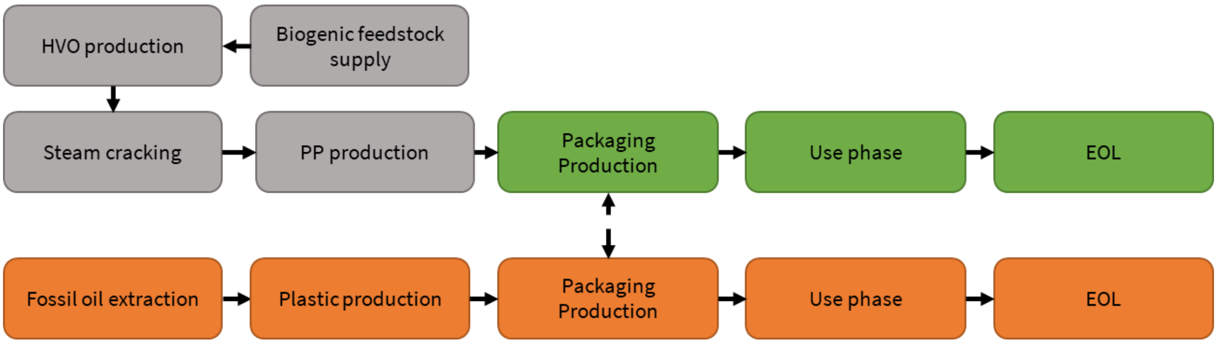

Figure 2 *Depiction of system boundaries of bioPP production. The assessed system comprises the life cycle of products made of bioPP and potential displacements of conventional plastic products. Green processes will commence/increase operation due to the increase in demand for alternative plastics; orange processes will cease to operate or reduce their production. Abbr.: EOL – End-of-life, HVO - hydrotreated vegetable oil, PP - polypropylene.*

2.3.3. bioPE

As an alternative to conventional PE production via hydrocracking of fossil hydrocarbons, the conversion of bioethanol to ethylene is a process that is already conducted at industrial scales (Jamil et al. 2022; Siracusa and Blanco 2020). First, bioethanol is produced and converted to bioethylene. Subsequently, bioPE can be synthesized from bioethylene as done with fossil-based ethylene (Jamil et al. 2022). The largest production capacities are located in Brazil, where 69% of global product capacities are located. The main feedstock used to produce ethanol is sugarcane. In this assessment the production of bioPE using ethanol from sugarcane grown in Brazil and cereals (rye) grown in the EU are assessed. The inventory of feedstock supply was taken from the ecoinvent database (Wernet et al. 2016) and (Chagas et al. 2016). The synthesis of bioethylene from ethanol was modeled with data provided in (Akmalina and Pawitra 2020). The synthesis of bioPE from bioethylene was assessed by using data for conventional synthesis of fossil-based PE using a Ziegler-Natta catalyst (Wernet et al. 2016).

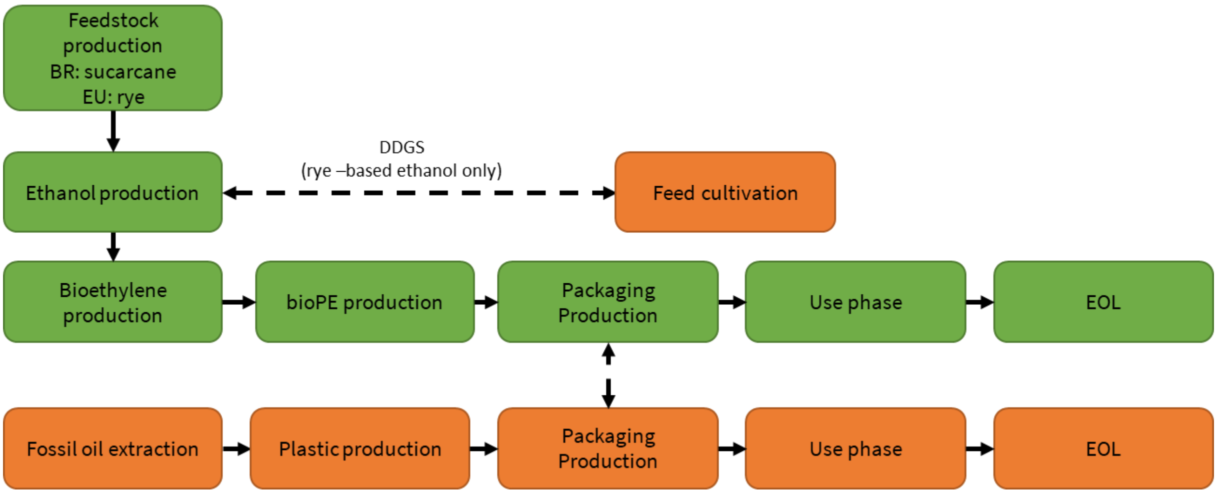

Figure 3 *Depiction of system boundaries of bioPE production. The assessed system comprises the life cycle of products made of bioPP and potential displacements of conventional plastic products. Green processes will commence/increase operation due to the increase in demand for alternative plastics; orange processes will cease to operate or reduce their production. Abbr.: BR - Brazil, EOL – End-of-life, EU - European Union, HVO - hydrotreated vegetable oil, PE - polyethylene.*

2.3.4. PLA

PLA is the most common substitute for conventional plastic by production capacity (Institute for Bioplastics and Biocomposites (IfBB) 2020). Lactic acid can be produced via fermentation of starch or sugars. Purified lactic acid can be further converted to PLA. Several different processes are currently used on a commercial scale. NatureWorks LLC, the largest producer of PLA uses a solvent-free polymerization process (Castro-Aguirre et al. 2016). At first, lactic acid is condensed to form a low molecular weight preplymer PLA. Subsequently, lactide is produced via controlled depolymerization. Subsequently, polymerization is achieved using a catalyst. The data used in this study stems from NatureWorks, Nebraska US, as provided in (Wernet et al. 2016). In this study, PLA production using corn growing in the US is assessed (Figure 4).

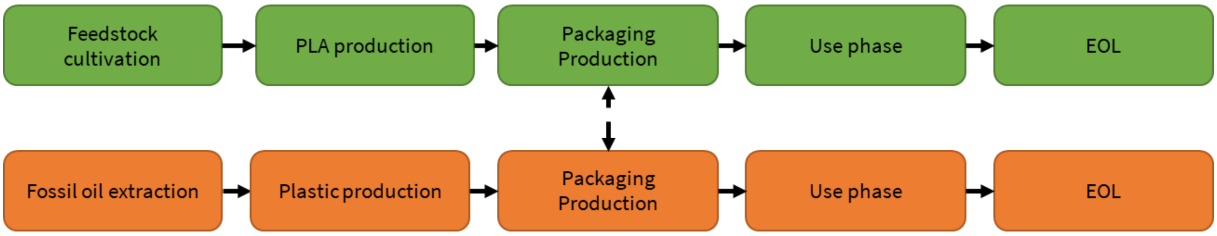

Figure 4 *Depiction of system boundaries of PLA production. The assessed system comprises the life cycle of products made of bioPP and potential displacements of conventional plastic products. Green processes will commence/increase operation due to the increase in demand for alternative plastics; orange processes will cease to operate or reduce their production. Abbr.: EOL – End-of-life, PLA - polylactic acid.*

2.3.5. PBAT

PBAT is a fossil-based, compostable polyester made from butanediol, adipic acid and terephthalic acid by the aif of organometallic catalysts (Jian, Xiangbin, and Xianbo 2020) (Figure 5). PBAT can be used as a mono compound or as a blend with other materials, such as PLA. Among all assessed alternatives, the fewest studies and data was available on PBAT. The model is based on the materials and energy demands reported in (Broeren et al. 2017; Schrijvers et al. 2014).

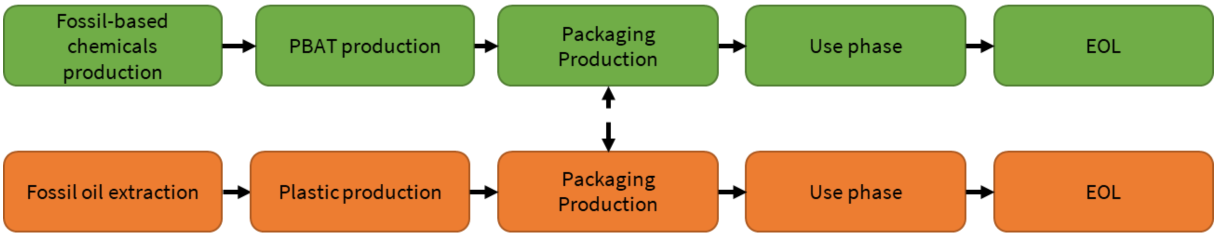

Figure 5 *Depiction of system boundaries of PBAT production. The assessed system comprises the life cycle of products made of bioPP and potential displacements of conventional plastic products. Green processes will commence/increase operation due to the increase in demand for alternative plastics; orange processes will cease to operate or reduce their production. Abbr.: EOL – End-of-life, PBAT - polybutylene adipate terephthalate polylactic acid.*

2.4. Affected markets and displacement effects

Most importantly, traceless affects the feed markets and the EOL of plastics.

2.4.1. Feed markets

Several of the assessed products affect the food and feed markets:

- traceless uses an animal feed to produce bio-based plastic substitutes. In addition to this influence on the feed markets, the production process yields a feed product. Thus, the potential effect on the feed market is two-fold:

    1. traceless' feedstock is currently used as an animal feed. If traceless uses this feedstuff to produce its materials, less of this feedstuff is available to the animal feed market. This missing feed is likely to be compensated by other means of animal feed production. There won't be any additional production of the used material because the material is a low-value by-product of a production process in the food and feed industry. Thus, its supply is inflexible and only dependent on the overall production of the primary product of its production process. Instead, another feed supply will most likely provide feed to the feed market. The used feed is high in proteins, but lacks essential amino acids. Thus, it is likely that the feedstuff used by traceless as feedstock is currently used as an additional energy feed to high quality protein feed (e.g. soybean meal). In order to consider different potential displacement mechanisms, three scenarios were considered (labeled "F" for "feed market").
    2. Traceless also produces a feed product, which is likely to displace feed on the market.

3. Traceless uses some consumables that result in displacements on the agricultural market (type and quantity are confidential but known to Planet A and considered in the assessment). The substitution was considered according to the scenarios described below.

- Most bioethanol production facilities using cereal grains produce a feed from the residual biomass. The dried distiller's grains with solubles (DDGS) is a high-protein feed. BioPE is made from ethanol. In this case, such a substitution effect is considered.

Because potential substitution effects and substitution quantities are subject to uncertainty, three different methods to calculate substitution ratios of feed, labeled "F1", "F2" and "F3", are considered. In scenarios F1 and F2, a substitution based on the protein content is applied for DDGS (because DDGS is a high-protein feed).

The base case:

- **F1 "energy feed"**. Due to the low content of essential amino acids, it is assumed that the feedstock used by traceless is currently used as an energy feed for animals. Therefore, a potential substitute could be cereal grains. In this scenario, a substitution based on the metabolizable energy is assumed for the feedstock and traceless feed.

In a **sensitivity analysis**, two additional scenarios were evaluated:

- **F2 "protein feed"**. In this scenario, the feedstock and therefore traceless feed are considered protein feed. Soybean meal is considered the marginal supply of protein feed. It is assumed that farmers will adjust their feed composition (once the feedstock is used by traceless) according to the usable protein content of feed. Soybean meal is considered the marginal supply of protein feed. The market for rapeseed meal, a potential alternative to soybean meal, is controlled by the demand for vegetable oil (mainly for biodiesel production) (Union zur Förderung von Oel- und Proteinpflanzen 2020). The supply of protein feed from soybeans also yields vegetable oil. Thus, a change in demand/production for soybean meal affects the marginal supply of vegetable oil, cf. (Dalgaard et al. 2008; Reinhard and Zah 2009; Schmidt and Weidema 2008; Weidema 2003). Globally, palm oil is the marginal supply of vegetable oil. For example, when soybean protein feed production increases, vegetable soybean oil production also increases. This results in a decrease in demand for other vegetable oil on the global market.
- **F3 ("combination")**. In this scenario, it is assumed that the feedstock was formerly used as a source for energy and proteins (i.e. farmers reduced the amount of protein fed according to the protein content of the feedstock). In this case, the substitution ratio is determined by a linear equation system (Lywood, Pinkney, and Cockerill 2009):

$$uP_{FS} = \lambda\, uP_{protein\,feed} + \mu\, uP_{cereal}$$

$$ME_{FS} = \lambda\, ME_{protein\,feed} + \mu\, ME_{cereal}$$

Where uP, ME, λ and μ denote the usable protein content, the metabolizable energy for cattle and the displacement ratios of the used feedstock (FS), proteins feed and cereals, respectively (Lywood, Pinkney, and Cockerill 2009). This scenario furthermore includes additional displacement effects: The displacement of oil (as considered in scenario F2), results also in a displacement of meal. If this meal is provided by meal production by the marginal supplier of the meal, oil is produced again. This triggers a reduction in oil supply, triggering a reduction in meal supply, etc.

These mechanisms can be expressed mathematically by a converging series. The procedure is explained in detail in (Buchspies and Kaltschmitt 2018).

The different approaches to consider the potential substitution of feed result in different substitution ratios (Table 1).

Table 1 *Substitution ratios for the feedstock (formerly used as a feed), traceless feed (a co-product of the process) and DDGS. Scenario F1 is the base case. Scenarios F2 and F3 are considered in a sensitivity analysis.*

	Mechanism	Calculation based on	Soybean meal	Wheat	Palm oil
F1	Increase in feed demand (feedstock)	Metabolizable energy (ME)		1.14	
	Decrease in feed demand (traceless feed)			-0.96	
	DDGS from ethanol production		-1.08		
F2	Increase in feed demand (feedstock)	Usable	0.21		-0.06
	Decrease in feed demand (traceless feed)		-0.08		0.02
	DDGS from ethanol production		-1.08		
F3	Increase in feed demand (feedstock)	ME and uP	0.23	0.93	0.07
	Decrease in feed demand (traceless feed)		0.01	-1.05	<0.01
	DDGS from ethanol production		-1.48	0.42	1.23

- This demand is reduced due to additional soy production
+ this demand increases (substituted by soy)

2.4.2. EOL

2.4.2.1. EOL recyclable plastics

A crucial aspect of the evaluation is the EOL of plastic products. Available waste statistics, scientific literature and market analyses were evaluated to derive EOL scenarios. Usually, plastic consumer waste is either disposed of with municipal solid waste (MSW) or collected in a separate collections system. The former is mostly incinerated in MSW treatment plants. In certain EU countries, MSW is also landfilled. Separately collected plastics are either recycled, incinerated in MSW facilities, landfilled or exported. Exported waste is either incinerated, recycled or landfilled. A share of the overall waste ends up in the environment due to mismanagement and dissipative loss. The following processes were modeled with the Ecoinvent datasets (Wernet et al. 2016) and adjusted according to the descriptions below:

- **Recycling**. Eurostat reports a recycling rate of 69.9% for packaging waste in Germany in 2017 and even lower numbers in other European countries (Eurostat 2020b). Studies reveal that the share of plastics recycled into recycled material (fate a) above) is much lower than claimed in official statistics (Wecker 2018). For example, one study estimates that in 2017, the actual recycling shares (defined as recyclate produced per plastic waste arising) were 30 and 17% of total and post-consumer plastic waste, respectively (Conversio Market & Strategy GmbH 2018). Hsu et al. 2021 found that 11% of plastic waste arising within the EU is recycled to replace virgin material (Hsu, Domenech, and McDowall 2021).

- **Incineration**. Around 42% of waste remaining within the EU was incinerated in 2016 (most actual study found), comprising incineration with (23%) and without (19%) energy recovery (Hsu et al. 2021). During incineration, while energy is produced, the carbon contained in the material is oxidized and emitted in the form of $CO_{2.}$ In the case of biobased materials, this carbon is of biogenic origin meaning that the emission of the material bound carbon can be considered climate neutral.
- **Landfilling.** Landfilling of inert waste results in storage of carbon contained in the landfilled material. According to the EU JRC’s Plastic LCA method, a degradation of 1% for conventional materials (PP, PE, PET, bbPP and bioPE) is considered (Nessi et al. 2021). Therefore, landfilled biobased plastics, such as bbPP and bbPE result in a storage of biogenic carbon. Around 18% of plastic waste remaining within the EU was landfilled in 2016.
- **Industrial composting.** Biowaste can be processed in industrial composting facilities. In such facilities, biowaste degrades under aerobic conditions, producing a humic substance containing nutrients (compost). A share of carbon contained in the material is oxidized and emitted in the form of CO_2 over time. In the case of biobased materials, this carbon is of biogenic origin, meaning that the emission of the material bound carbon is climate neutral. The European Environmental Agency considers composting the third best solution after prevention and re-use and anaerobic digestion (European Environment Agency 2020). A challenge stressed out by the European Environmental Agency is biodegrability and compostability of bioplastics and other biodegragable/ compostable materials. Some materials, such as traceless material, are fully biodegradable within a few weeks. In contrast, other materials are only compostable, if managed in an industrial composting facility. So far, there is no consistent comprehensive data available on separate biowaste collection and treatment in the EU. The available data suggest a highly variable share of separately collected organic waste across EU member states. An average of 50% of biowaste is separately collected in those countries that provided data. Likewise, the treatment capacity ranges from 0 to 356 kg per capita in different European countries. This indicates a high potential for improvement. It indicates too, that materials that require industrial composting facilities or anaerobic digestion might not end up in these but are rather collected in the mixed MSW fraction.
- **Mismanaged waste.** A considerable share of exported waste is assumed to end up in nature (ocean and land debris) (Bishop, Styles, and Lens 2020). The study reports that Germany is the largest contributor to ocean debris among EU member states in absolute terms: 10 000 to 57 000 t of PE waste in 2017 is estimated to have ended up in the ocean, corresponding to 32% of all ocean debris originating from EU-28 exports in 2017 and the fourth highest per capita quantity of ocean debris among EU-28 member states. While the

environmental impact of mismanaged waste is expected to have multiple negative effects on the ecosystems, e.g. affecting biodiversity, it is not covered by the assessed indicators.

A considerable share of plastic waste arising within the EU is exported by member states (intra-or extra-European trade). In 2018, ca. 15 million tonnes of plastic packaging waste was generated within the EU-28 (Eurostat 2021). Of these, about 1.5 mio tonnes were exported (Eurostat 2020a). EU statistics reveal that until the end of 2017, the quantity of plastic waste exported steadily increased. In 2018, a ban on plastic waste imports came into effect in China. This resulted in a decrease in waste exports in the following years (Eurostat 2020c). The Chinese ban on plastic waste imports prompted a global decrease in plastic exports as well as a shift in waste trade flows from China to other countries, such as Vietnam, Thailand, Malaysia and Turkey (Greenpeace 2019). As a consequence of increasing waste imports to these countries, many of the importing countries imposed import restrictions. Often, these countries lack adequate systems to ensure a proper recycling of the material, bearing a high risk of waste leakages to the environment. The fate of exported material is hard to trace (Bishop, Styles, and Lens 2020). The statistics provided by the EU use inconsistent definitions of recycling quotas, e.g. Germany reports the share of plastic going into the recycling system (of which a high share is incinerated). Thus, reported numbers do not reflect real recycling quotas (if these are meant to express the share of material that is really recycled).

Country-specific shares of different waste treatment options (i.e. landfilling, incineration with and without energy recovery) for PE and PP provided by the Ecoinvent 3.8 database were used in the calculations (Wernet et al. 2016). Based on statistics reported in this section, the following waste treatment scenarios, labeled T, were developed (Table 2):

Table 2 *EOL scenarios.*

Fate of waste	**Base case**	**Sensitivity analysis**	
	T1: average	T2: high recycling	T3: high ocean
EU treatment (excl. recycling)	79.00%	65.00%	69.00%
Recycled (Within EU and export)	18.60%	33.30%	24.80%
Export: landfilled	1.42%	0.87%	3.47%
Export: Incinerated	0.68%	0.73%	1.33%
Export: Ocean	0.30%	0.10%	1.40%
Industrial composting			

2.4.2.2. EOL of biodegradable/compostable materials

Not all wastes are equally suitable for different waste treatment options. Recyclability of biodegradable/compostable materials is limited in existing recycling facilities due to their low market share and respective low mass of occurring total waste. Of the assessed materials, traceless materials, PLA and PBAT are biodegradable/compostable and thus technically suitable for industrial composting. However, the actual availability of infrastructure for biowaste treatment varies greatly from region to region (see 2.4.2.1 industrial composting), meaning that this disposal option is not available everywhere. Furthermore, in some regions the biowaste disposal companies generally prohibit compostable plastic alternatives from being added to their waste, as their facility conditions are not suitable for materials that are certified for industrial composting (EN 13432), and their regulations do not consider materials that are easier to compost (like traceless materials). Taken together, assuming the current infrastructure in Europe and the current regulatory framework, it is likely that not all of the end products made from the above-mentioned compostable materials do actually end up in industrial composting facilities. Thus, the scenarios of traceless material, PLA and PBAT are according to those scenarios listed in Table 2 with the exception that the recycling share is assumed to end up in an industrial composting facility. In all cases, the arising GHG emissions from the oxidation of carbon contained in the different materials were adjusted based on the organic carbon content. The carbon content of different material types as well as degradation rates were from literature (Smeaton 2021; Nessi et al. 2021; Castro-Aguirre et al. 2016; Weng et al. 2013).

3. Results

The following section presents the change in environmental indicators by traceless materials and the other assessed materials. At first, tracless impact is discussed in detail in sections 3.1 and 3.2. A comparison of all materials assessed is provided in section 3.3. All results refer to one kg of traceless material produced. The results present net changes in indicator scores comprising all changes as depicted in Figure 1 and as described in sections 'System boundaries' (section 2.3) and 'Affected markets and displacement effects' (section 2.4).

3.1. GHG emissions

traceless is likely to reduce GHG emissions (Figure 6). In all feed displacement and waste treatment scenarios, **traceless results in a decrease in GHG emissions ranging from -0.7 to -2.8 kg CO_2-eq. (average -1.6 kg)**. **In the base case scenario, traceless material results in a net reduction in GHG emissions of -2.0 kg CO_2-eq. per kg.** The highest reduction in GHG emissions can be achieved by displacing PET. There is only a small difference between LDPE, HDPE and PP. The displacement of virgin production is the largest contributor to a reduction in GHG emissions. The largest single contributor to the GWP of traceless' operation are consumables used, accounting for 60% of emissions related to traceless' production process (including all upstream (background) processes). The remainder is caused by transportation processes and energy supply. Traceless significantly lowered their GHG emissions related to their activities due to the switch from natural gas and grid electricity to fully renewable energy supply (biomass and certified electricity from renewable sources). The production of traceless material and upstream processes of material and energy supply sum up to 0.85 kg CO_2-eq. per kg material produced. **The production and disposal of traceless material emits between 88 and 95% less GHG emissions compared to the production and disposal of virgin plastics. The overall net reduction (including all displacement effects) in GHG emissions is 26 to 76% of the GHG emissions of virgin plastic production and disposal.**

The internal use of the produced side-stream results in less feed supplied to the market. This results in less feed displaced and hence, lower substitution credits. This results in a slight increase in GHG emissions. Another change in emissions stems from the harmonization of the applied methodology (see the Changelog in section A.2 if the Annex and section 3.4).

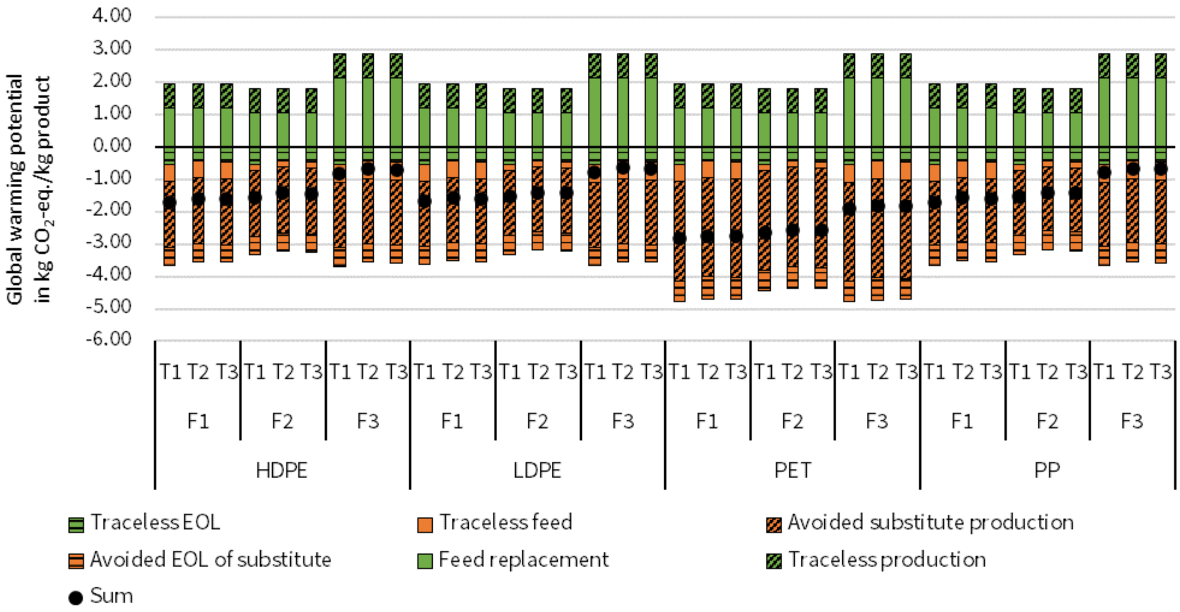

Figure 6 *Change in GHG emissions. Scenarios are abbreviated as described in section 'Affected markets and displacement effects'. Abbr.: EOL – End-of-life; LDPE – low-density polyethylene; HDPE – high-density polyethylene ; PET – polyethylene terephthalate ; PP – polypropylene. All values used in this graph can be found in table A.1 in the annex.*

3.2. Resources

In total, four indicators were evaluated that describe the change in demand for different types of resources: abiotic resource depletion, fossil energy resource use, water and land demand.

3.2.1. Abiotic depletion

The ever-increasing demand for plastics and the existing dysfunctional recycling systems result in increasing demands for virgin, fossil-based plastic. traceless offers the potential to displace the virgin production of plastics. The results show a mixed picture: in about two thirds of the scenarios, an increase in abiotic resources can be observed (Figure 7). **The observed net range of the change in abiotic resource depletion potential is -9.0 to 63.6 10^{-6} kg Sb-eq. per kg traceless material.** traceless switched to electricity from renewable sources. The increase in demand for renewable energy technologies results in an increase in abiotic resources[4]. This phenomenon can also be

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[4] Characterization factors are used in LCA to derive a single unit to compare impacts. The characterization factors express the contribution of a resource use or emission to a specific mechanism, e.g. climate change or abiotic resource demand. The total quantity of a resource use or an emission, e.g. copper or a GHG that is emitted, is multiplied by a characterization factor that expresses this contribution in relation to a reference substance, e.g. CO_2 in case of the global warming potential (climate change) and antimon in case of the CML abiotic depletion method. For instance, the characterization factor of methane expresses how much solar radiation methane absorbs over a specific period of time (e.g. 100 years) in relation to CO_2. Analogously, the

observed in many other LCA, for example those comparing conventional, fossil based electricity supply and electricity from renewable sources, cf. chapter 4.7 in (United Nations 2021).

The most important resource demand as a consequence of traceless' operation aside from renewable electricity supply originates from the increase in demand for animal feed that is substituted by traceless. The abiotic resource demand results from fertilizer production that is needed to cultivate the feed that displaces the feedstock used to produce traceless material. The abiotic resource demand of traceless production originates from the supply of auxiliary materials. For example, certain biobased consumables are crop-based. The cultivation of these crops requires mineral fertilizer, too. The abiotic depletion accounts for the production of these fertilizers.

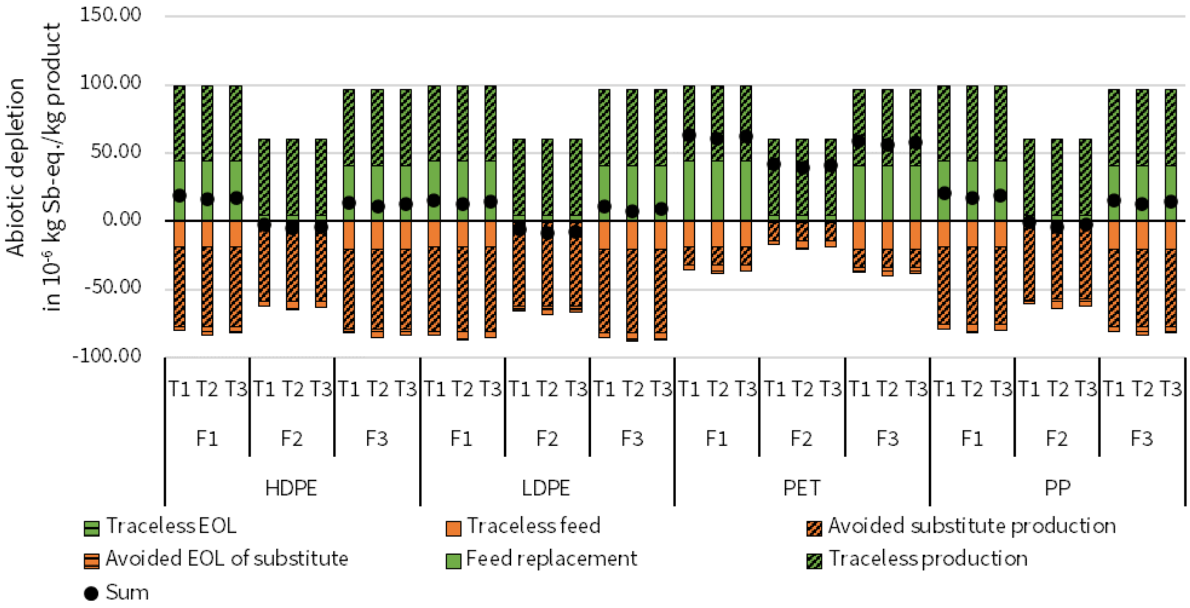

Figure 7 Change in abiotic depletion potential. Scenarios are abbreviated as described in section 'Affected markets and displacement effects'. Abbr.: EOL – End-of-life; LDPE – low-density polyethylene; HDPE – high-density polyethylene ; PET – polyethylene terephthalate ; PP – polypropylene.

3.2.2. Cumulative fossil energy demand

traceless results in a net reduction in fossil energy demand of -54.8 to -65.0 (average -58.9) MJ per kg traceless material (Figure 8). The net decrease in the demand for fossil energy resources stems from the displacement of virgin plastic. The production of virgin plastic requires energy that is (today) predominantly supplied using fossil energy carriers. In addition, conventional plastics are

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resource demand in the CML abiotic depletion method expresses the resource use in relation to antimon (Sb). In the CML method, abiotic depletion potential of all resources (e.g. copper and the reference substance antimon) is calculated using the actual resource extraction rate of each divided by the ultimate reserve of each resource squared. The result of copper is then divided by the result of antimon, resulting in the desired unit kg Sb-eq/kg copper. The abiotic resource depletion is therefore an expression of how much of the remaining reserve is annually extracted of a specific metal normalized by the same value obtained for antimon. More information and explanations on the global warming potential and the abiotic depletion can be found here and here.

made from fossil energy resources. Since the previous report, the results show an even higher net decrease in fossil energy demand. This is mainly due to the switch from a natural gas-fired boiler to the use of biomass (internal use of side-stream) and electricity from renewable sources.

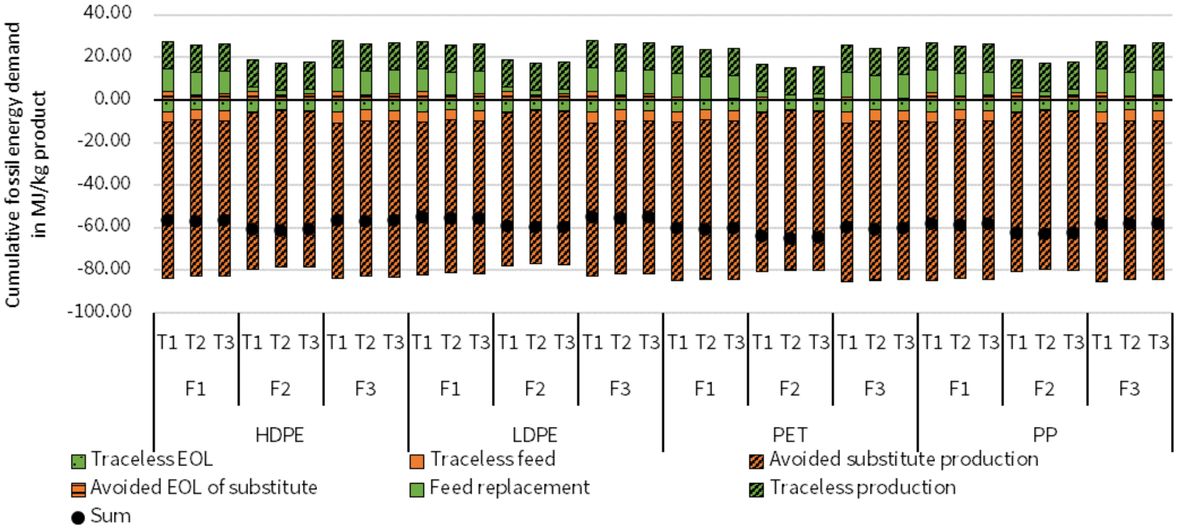

Figure 8 Change in cumulative fossil energy demand. Scenarios are abbreviated as described in section ‘Affected markets and displacement effects’. Abbr.: EOL – End-of-life; LDPE – low-density polyethylene; HDPE – high-density polyethylene ; PET – polyethylene terephthalate ; PP – polypropylene.

3.2.3. Water demand

The change in water demand ranges from -0.3 to 0.16 (average -0.02) m^3 per kg (Figure 9). In 58% of the calculated scenarios, traceless results in a net reduction in water demand. For comparison: the production of virgin PP, HDPE, LDPE and PET result in a water demand (WSI) of 0.10, 0.11, 0.21 and 0.32 m^3 per kg. The highest water demand triggered by traceless is the cultivation of animal feed that substitutes traceless’ feedstock. The new energy concept resulted in more feedstock needed and less feed supplied to the market. This resulted in an increase in overall water demand since the last version of the LCA. The EOL affects water demand, too: if less high calorific waste is incinerated in MSW treatment plants, the demand for heat and power must be met by another energy source. At present, most MSW treatment capacity allows the provision of heat and power (Scarlat, Fahl, and Dallemand 2019). According to studies on the future energy supply, the marginal heat and power supply in Europe will be based on biomass (Fleiter et al. 2016; International Renewable Energy Agency (IRENA) 2018; Nijs, Castelló, and Ignacio Hidalgo González 2017). All fossil energy sources are predicted to be reduced. Hence, on a systemic perspective, a decrease in heat supply (e.g. by less plastic being incinerated in MSW plants),is likely to be met by energy supply from biomass. Please note: The marginal energy supply is strongly dependent on local infrastructure, such as existing MSW plants, heat supply infrastructure, availability of other heat sources,. Furthermore, it is highly uncertain if heat produced by MSW treatment facilities is utilized at all (requires a district heating system connected to the MSW treatment facility). The displacement of virgin plastic production and the increase in demand for certain organic consumables (triggering other displacement effects through the supply of co-products) result in a reduction in water demand.

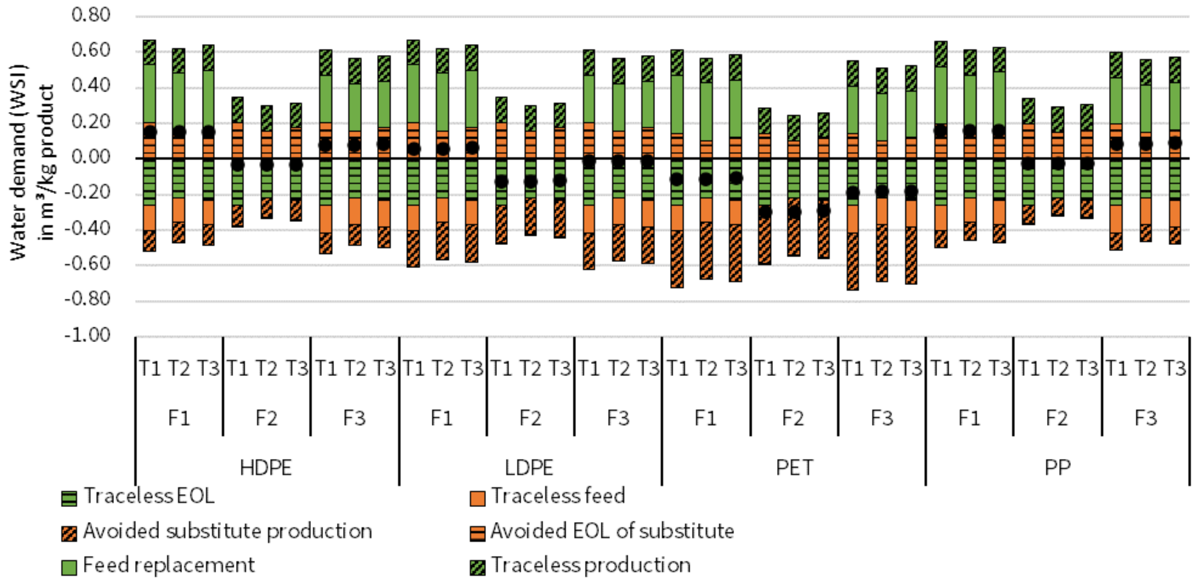

***Figure 9** Change in water demand. Scenarios are abbreviated as described in section 'Affected markets and displacement effects'. Abbr.: EOL – End-of-life; LDPE – low-density polyethylene; HDPE – high-density polyethylene ; PET – polyethylene terephthalate ; PP – polypropylene; WSI – Water stress index.*

3.2.4. Land demand

traceless' impact is determined by the land demand for agricultural products (Figure 10). **The net change in land demand ranges from -0.64 to 0.38 (average -0.1) m²a per kg material.** The change in results since the last version of the LCA can be attributed to an increase in feedstock demand and less feed supplied to the market. Whether traceless leads to an increase or decrease in land demand strongly depends on the feed market. The displacement effects on the feed markets (i.e. replacement for the feedstock and substitution of feed by traceless feed) as well as the demand for organic consumables[5] for the production process are the strongest contributors to land demand. The determined increase in demand for the bio-based consumables results in the provision of co-products that reduce land demand elsewhere (type and co-products known to Planet A but not published due to confidentiality reasons). All potential changes in land demand strongly depend on many factors, such as type of feed substituted, cultivation yields, etc. Furthermore, the impact on the environment of a change in land demand strongly depends on the location and existing conditions of land use and the surrounding environment. The demand for a certain type of land at a specific location, e.g. the area used for agricultural production has decreased in the past 20 years in Germany, where traceless sources its feedstock. Hence, a slight increase in demand for agricultural land (resulting from the cultivation of a feed replacement to replace the feedstock) will reduce the ongoing decrease in land demand. This is very likely to have a much lower negative impact on the environment compared to an increase in land demand in an area, where land demand strongly increases at the cost of natural habitats (e.g. land expansion for cattle or soybean production in Brazil). Thus, even a higher absolute increase in land demand (e.g. such as in scenario F1) might result in much lower environmental consequences compared to other scenarios (e.g. scenarios F2 and F3). Ultimately, the consequences of land demand depend strongly on local conditions and changes in the global feed market that traceless might trigger. Aside from the feed markets, substitution effects from energy provision by MSW plants are an important factor.

As discussed in section 3.2.3, marginal combined heat and power supply is expected to be provided by biomass-based energy generation. Similar effects as discussed in section 3.2.3 come into play regarding land-use.

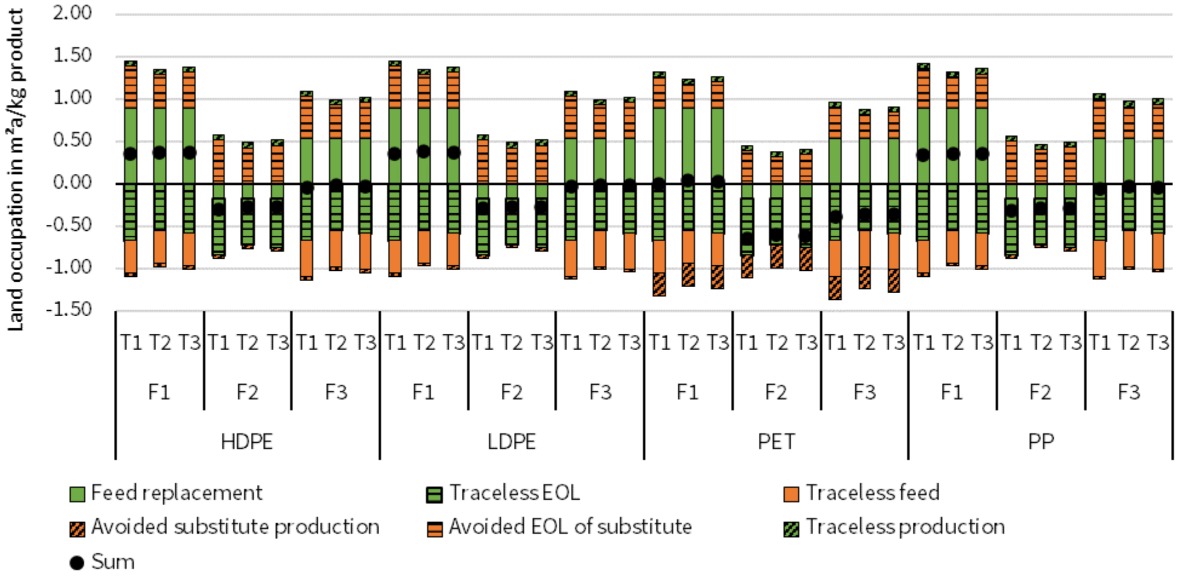

Figure 10 *Change in land demand. Scenarios are abbreviated as described in section 'Affected markets and displacement effects'. Abbr.: EOL – End-of-life; LDPE – low-density polyethylene; HDPE – high-density polyethylene ; PET – polyethylene terephthalate ; PP – polypropylene.*

3.2.5. Additional environmental considerations

3.2.5.1. Plastic waste

In many regions, dysfunctional waste handling systems result in the leakage of plastics to the environment. The leakage of plastics mainly occurs in Asia, where 82% of plastic leakage is estimated to occur (World Economic Forum, Ellen MacArthur Foundation, and McKinsey & Company 2016). The United States and Europe are estimated to account for 2% of the total plastic leakages. All other countries account for the remaining 16% of plastic leakages. Plastic pollution poses an irreversible threat (MacLeod et al. 2021). Even under optimistic scenarios, emissions of plastics are expected to continue and increase. Once in the natural environment, the material is subject to degradation processes. The rate of degradation depends on intrinsic properties of the material (material type, additives, etc.), the environmental conditions (temperature, moisture, contact with other substances and molecules, etc.) as well as the extrinsic material properties (e.g. shape, particle size): estimates range from very short periods of time in case of biodegradable materials to millennia in case of larger solid objects, e.g. pipes made from HDPE or bottles made from PET (Chamas et al. 2020). Once in nature, plastic and plastic particles are subject to many different mechanisms, such as fragmentation, biofouling and oxidation, resulting in the release of smaller, more mobile and potentially more harmful substances.

The release of these substances results in organisms being exposed to potentially harmful substances. The plastic polymers used are made from polymers mixed with additives and processing aids. Examples of additives are antioxidants, biocides, fillers, flame retardants, impact modifiers, light stabilizers, nucleating agents, odor agents and plasticizers. A few examples of the most common processing aids are antistatic agents, blowing agents, catalysts, crosslinking agents, heat stabilizers, initiators, lubricants, solvents and viscosity modifiers. There are over 10,000 known substances contained in plastics used today of which more than 2,400 are of potential concern (Wiesinger, Wang, and Hellweg 2021). Of these ca. 53% are not subject to any management measure or regulation. About 4,100 substances lack a hazard classification. Hence, their level of concern is unknown. Organisms are exposed to these substances through direct contact, ingestion and inhalation. This exposure can happen through contact with the material containing the substances or through the leakage of the substances into the environment and a subsequent exposure to the substance or to its derivatives. Many of these are toxic, cancerogenous, mutagenic or endocrine disrupting and accumulate in organisms (bioaccumulation) (Wiesinger, Wang, and Hellweg 2021).

The prevention of plastic waste therefore substantially reduces the risk for these negative effects. Among compared alternatives to conventional plastic only traceless material degrades within a short time frame under natural conditions (results of laboratory experiments were provided by traceless). Other biobased materials were observed to not degrade fully, even after several months, cf. (Fu et al. 2020). Scientific literature stresses out that the degradation of materials strongly depends on the environmental conditions (Pires et al. 2022).

traceless reduces the amount of plastic that needs to be treated. At present, the existing end-of-life treatment of plastic wastes in Europe is largely relying on incineration, recycling, export and even landfilling. Exported waste is either recycled, incinerated, landfilled or ends up in nature. Only a minor share of plastic consumer waste is recycled at present (see section 2.2.2). Such a dysfunctional system results in the leakage of plastic to the environment as well as material losses as recycling loops are not closed. traceless material fully closes all material cycles in a cradle-to-cradle approach.

3.2.5.2. Toxic compounds and additives

The release of plastic to the environment results in organisms being exposed to potentially harmful substances. The plastic polymers used are made from polymers mixed with additives and processing aids. Examples of additives are antioxidants, biocides, fillers, flame retardants, impact modifiers, light stabilizers, nucleating agents, odor agents and plasticizers. A few examples of the most common processing aids are antistatic agents, blowing agents, catalysts, crosslinking agents, heat stabilizers, initiators, lubricants, solvents and viscosity modifiers. There are over 10,000 known substances contained in plastics used today of which more than 2,400 are of potential concern (Wiesinger, Wang, and Hellweg 2021). Of these ca. 53% are not subject to any management measure or regulation. About 4,100 substances lack a hazard classification. Hence, their level of concern is unknown. Organisms are exposed to these substances through direct contact, ingestion and inhalation. This exposure can happen through contact with the material containing the substances or through the leakage of the substances into the environment and a subsequent exposure to the substance or to its derivatives. Many of these are toxic, cancerogenous, mutagenic or endocrine disrupting and accumulate in organisms (bioaccumulation) (Wiesinger, Wang, and Hellweg 2021).

traceless material does not contain toxic additives that pose a potential harm to the environment. Hence, the biodegradation, which takes place under natural conditions within a short period of time, does not result in any release of harmful substances.

3.3. Comparison of all materials

Table 3 summarizes the results. The overall results show that there is not a single perfect solution to displace conventional plastics.

Table 3 *Summary of results per kg traceless material. Units: abiotic depletion in 10^{-6} kg Sb-eq., climate change in kg CO_2-eq./kg, land demand in m^2a/kg, cumulative fossil energy demand in MJ/kg and water demand in m^3/kg*.

			Base case: F1 T1	All scenarios		
Material	**Origin**	**Indicator**	**Average**	**Average**	**Min**	**Max**
traceless	EU	Abiotic depletion	29.50	19.40	-8.99	63.64
		Climate change	-1.98	-1.55	-2.81	-0.65
		Land demand	0.27	-0.06	-0.64	0.38
		Cumulative fossil energy demand	-57.35	-58.91	-64.95	-54.79
		Water demand	0.06	-0.02	-0.30	0.16
bioPE	EU	Abiotic depletion	109.55	119.07	92.36	175.32
		Climate change	0.07	0.25	-0.81	0.90
		Land demand	-0.37	0.20	-0.71	1.58
		Cumulative fossil energy demand	55.86	56.91	51.33	64.31
		Water demand	2.40	2.50	2.18	2.84
bioPE	BR	Abiotic depletion	80.52	79.62	63.33	115.53
		Climate change	-6.69	-6.68	-7.57	-6.37
		Land demand	1.68	1.63	1.34	1.78
		Cumulative fossil energy demand	-86.64	-87.62	-91.17	-84.30
		Water demand	-3.33	-3.35	-3.55	-3.24
bioPP	EU	Abiotic depletion	-49.25	-50.15	-66.43	-14.23
		Climate change	-0.23	-0.23	-1.12	0.08
		Land demand	0.38	0.33	0.04	0.48
		Cumulative fossil energy demand	-20.80	-21.78	-25.33	-18.45
		Water demand	0.03	0.00	-0.20	0.12
PLA	US	Abiotic depletion	-0.42	-1.74	-17.61	33.72
		Climate change	0.21	0.21	-0.68	0.52
		Land demand	-0.19	-0.34	-0.63	-0.19
		Cumulative fossil energy demand	-19.83	-20.82	-24.35	-17.52
		Water demand	0.22	0.20	0.00	0.31
PBAT	EU	Abiotic depletion	-74.17	-75.48	-91.35	-40.03
		Climate change	7.78	7.79	6.90	8.10
		Land demand	-0.05	-0.10	-0.39	0.05
		Cumulative fossil energy demand	56.71	55.71	52.18	59.01
		Water demand	1.40	1.38	1.18	1.50

3.4. Discussion of changes in results since the last report

The update of the LCA resulted in several changes in overall results (*new value*; *value of previous version*):

- **Abiotic depletion in 10^{-6} kg Sb-eq./kg (29.5; -5.7).** Traceless switched to fully renewable electricity and heat supply. Renewable electricity facilities require more abiotic resources (other than fossil fuels) than conventional energy supply.
- **Climate change in kg CO_2-eq./kg (-2.0; -1.7).** The GHG emissions related to traceless material production decreased thanks to the switch to renewables. The decrease in GHG emissions of traceless is compensated by a change related to methodology harmonization. In the previous version, the certain substitution effects affecting agricultural products were taken from the Ecoinvent database. In the updated version, GHG emissions are considered as defined in the methodology section for other feed products (section 2.5.1). This results in a change in GHG emissions related to the substitution occuring.
- **Land demand in m2a/kg (0.3; -0.58).** The reason for the increase in land demand is two-fold: first, traceless uses a part of the produced feed to produce heat. This results in less feed displacement on the feed market. Second, the change in the consideration of the substitution effect.
- **Cumulative fossil energy demand in MJ/kg (-57.4; -43.9).** The switch to renewable energy supply results in a net decrease in fossil energy resources.
- **Water demand in m^3/kg (0.1; 0.03).** The increase in water demand estimated in this report results from an increase in feedstock per kg material used by traceless (that is compensated by other feed supply), less feed produced (resulting in less feed supplied to the market, hence less feed substitution) and the harmonization of the methodology (see climate change above).

A list of most important changes contained in the updated version of the LCA is provided in the Changelog in the Annex.

4. Conclusion

The conducted LCA of traceless material shows that…

- ...the production and disposal of **traceless emits up to 95% less GHG emissions than the production and disposal of virgin plastic**,
- ...the overall **net reduction in GHG emissions amounts up to 26 to 76%**.
- ...traceless material reduces substantially **the demand for non-renewable energy resources**
- **...traceless offers several additional environmental benefits, such as the elimination of the risk of leakage of harmful substances to the environment**.

The results show that the net change in environmental impacts is caused by processes that are outside of the production chain of traceless. For example, traceless uses a feedstock that is currently used as an animal feed. traceless has no influence on farmer's choices regarding feed. In impact categories dominated by changes in the agricultural sector or feed markets, there are many variables that ultimately determine the impact on the environment, such as substitution effects controlled by feed availability, market price, farmers' preferences, as well as agricultural yields, co-products that displace other products, etc. as well as local environmental and socio-economic conditions. It should be noted that land demand itself is not an environmental impact per se. The change in land demand and land occupation lead to consequences that affect the environment. Therefore, it is of importance where such a change in demand increases occurs and which environmental consequences arise thereof.

In addition to global feed markets, traceless' impact depends to a large extent on the existing waste treatment system. In many countries, current waste treatment practice is far from optimal: only a minor share of material is recycled whereas a large share of waste is either landfilled, exported or incinerated. In the latter case, heat and electricity can be recovered. These currently dysfunctional systems result in the pollution of the environment and waste of (finite) resources. traceless offers an alternative to this non-circular way of producing and disposal of products by saving fossil energy resources while also reducing GHG emissions. **Other positive environmental effects (not considered in this LCA) could potentially arise from traceless**:

- The **reduction of plastic waste** that pollutes the environment goes beyond effects that are evaluated within this study. The impact on biodiversity and health were not evaluated. traceless offers a solution to significantly reduce the total amount of plastic waste and thereby environmental pollution through plastic.

- The **absence of toxic and harmful additives** eliminates the risk of the leakage of such substances to the environment.

- The protein composition of traceless feed allows a more complete digestion and use of protein by animals, resulting in less proteins that are excreted. This **reduces the emission**

of nitrogen-based pollutants (e.g. nitrate). Most of these compounds are harmful to the environment (in higher loads) due to their eutrophying effect and impact on the climate.

All alternative materials discussed in this study show net reductions in impacts in certain categories and net increases in others. This indicates that a tradeoff has to be made when displacing conventional plastic. This indicates that the selection of potential solutions cannot be based on the assessed indicators alone.

The update of the LCA revealed several changes, mainly arising from a change in substitution effects and the switch to electricity from renewable sources. These changes result in less GHG emissions that are directly emitted by traceless and upstream, but also effect substitution effects. Lowering emissions within the supply chain can result in increases elsewhere. traceless decision to move to renewable energy sources is a clear sign of commitment to reduce negative environmental impacts wherever possible within the own supply chain. Controversially, this has led to increases elsewhere. This paradoxical situation, which traceless and many other companies striving to improve their environmental impact find themselves in, will hopefully not lead to a reduction in effort.

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A. Annex

A.1 Additional results

Table A.1 *Values used in Figure 6.*

Substitute	**Scenarios**		**Feed market**		**Avoided substitute**		**Traceless**		**Sum**
	Feed	**EOL**	**Feedstock**	**Traceless feed**	**Production**	**EOL**	**Production**	**EOL**	
HDPE	F1	T1	1.20	-0.52	-2.02	-0.57	0.75	-0.55	-1.71
		T2	1.20	-0.52	-2.02	-0.56	0.75	-0.44	-1.59
		T3	1.20	-0.52	-2.02	-0.55	0.75	-0.47	-1.61
	F2	T1	1.04	-0.19	-2.02	-0.57	0.75	-0.55	-1.55
		T2	1.04	-0.19	-2.02	-0.56	0.75	-0.44	-1.43
		T3	1.04	-0.19	-2.02	-0.55	0.75	-0.47	-1.45
	F3	T1	2.14	-0.55	-2.02	-0.57	0.75	-0.55	-0.80
		T2	2.14	-0.55	-2.02	-0.56	0.75	-0.44	-0.68
		T3	2.14	-0.55	-2.02	-0.55	0.75	-0.47	-0.70
LDPE	F1	T1	1.20	-0.52	-1.99	-0.57	0.75	-0.55	-1.69
		T2	1.20	-0.52	-1.99	-0.56	0.75	-0.44	-1.56
		T3	1.20	-0.52	-1.99	-0.55	0.75	-0.47	-1.59
	F2	T1	1.04	-0.19	-1.99	-0.57	0.75	-0.55	-1.52
		T2	1.04	-0.19	-1.99	-0.56	0.75	-0.44	-1.40
		T3	1.04	-0.19	-1.99	-0.55	0.75	-0.47	-1.42
	F3	T1	2.14	-0.55	-1.99	-0.57	0.75	-0.55	-0.78
		T2	2.14	-0.55	-1.99	-0.56	0.75	-0.44	-0.65
		T3	2.14	-0.55	-1.99	-0.55	0.75	-0.47	-0.68
PET	F1	T1	1.20	-0.52	-3.06	-0.63	0.75	-0.55	-2.81
		T2	1.20	-0.52	-3.06	-0.68	0.75	-0.44	-2.75
		T3	1.20	-0.52	-3.06	-0.64	0.75	-0.47	-2.74
	F2	T1	1.04	-0.19	-3.06	-0.63	0.75	-0.55	-2.65
		T2	1.04	-0.19	-3.06	-0.68	0.75	-0.44	-2.58
		T3	1.04	-0.19	-3.06	-0.64	0.75	-0.47	-2.58
	F3	T1	2.14	-0.55	-3.06	-0.63	0.75	-0.55	-1.90
		T2	2.14	-0.55	-3.06	-0.68	0.75	-0.44	-1.84
		T3	2.14	-0.55	-3.06	-0.64	0.75	-0.47	-1.83
PP	F1	T1	1.20	-0.52	-1.97	-0.60	0.75	-0.55	-1.70
		T2	1.20	-0.52	-1.97	-0.59	0.75	-0.44	-1.57
		T3	1.20	-0.52	-1.97	-0.58	0.75	-0.47	-1.59
	F2	T1	1.04	-0.19	-1.97	-0.60	0.75	-0.55	-1.53
		T2	1.04	-0.19	-1.97	-0.59	0.75	-0.44	-1.40
		T3	1.04	-0.19	-1.97	-0.58	0.75	-0.47	-1.43
	F3	T1	2.14	-0.55	-1.97	-0.60	0.75	-0.55	-0.79
		T2	2.14	-0.55	-1.97	-0.59	0.75	-0.44	-0.66
		T3	2.14	-0.55	-1.97	-0.58	0.75	-0.47	-0.68

A.2 Changelog

Update 1, August 2022.

- Traceless changed their energy supply from fossil-based energy supply to fully renewable energy supply. Heat is supplied by biomass (internal use of side-stream). In addition, traceless only uses electricity from renewable sources.
- EOL of traceless products: Before, it was assumed that traceless fully degrades. Now, a share is also incinerated in a MSW incineration plant. This was included to use similar waste handling scenarios for all products.
- The scale-up and new energy supply (biomass) resulted in a change in feedstock demand and consumables.
- New products analyzed: In addition to traceless material, several other alternatives to conventional plastic are analyzed: bio-based PE (bioPE), bio-based PP (bioPP), polylactic acid (PLA) and polybutyrate adipate-terephthalate (PBAT). For these products, new product systems were modeled. Additional waste treatment scenarios were considered (industrial composting) for PLA and PBAT.
- Update of inventory data based on literature sources stated in this report and the update of the ecoinvent database (version 3.7 to version 3.8).
- The methodology was harmonized: The previous LCA contained an inconsistent handling of feed co-products. In the previous version not all feed products were considered as described in section 2.5.1. In the previous version, the substitution effect as modeled in the ecoinvent database was used in case of some bio-based consumable (Type and quantity known to Planet A). This inconsistency was corrected by applying the methodology described in section 2.51. to all feed products.

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