Standards and Regulations for the Bio-based Industry STAR4BBI

Work Package 4

D4.4 Regulation action plan

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Acronyms

C: Carbon

^{14}C: Radioactive isotope of carbon

CCU: Carbon capture and utilization

CH_4: Methane

CO: Carbon monoxide

CO_2: Carbon dioxide

DKR: Deutsche Gesellschaft für Kunststoffrecycling (German Society for Plastics Recycling)

EC: European Commission

EEA: European Environment Agency

EN: European Standards

EOL: End-of-life

EPR: Extended Producer Responsibility

ETS: Emissions Trading System

EU: European Union

GHG: Greenhouse gas

HDPE: High-density polyethylene

ILCD: International Reference Life Cycle Data System

IPCC: Intergovernmental Panel on Climate Change

JRC: Joint Research Centre

KIDV: Knowledge Institute for Sustainable Packaging

LCA: Life-cycle assessment

LDPE: Low-density polyethylene

LLDPE: Linear low-density polyethylene

LWP: Light weight packaging

MDPE: Medium-density polyethylene

MS: Member State

N_2O: Nitrous oxide

NIR: Near Infrared

OECD: Organisation for Economic Cooperation and Development

PA: Polyamide

PE: Polyethylene

PEF: Product Environmental Footprint

PEF: Polyethylene furanoate

PET: Polyethylene terephthalate

PHA: Polyhydroxyalkanoate

PHB: Polyhydroxybutyrate

PLA: Polylactic acid

PP: Polypropylene

PS: Polystyrene

RED: Renewable energy directive

rPET: Recycled polyethylene terephthalate

R&D: Research and Development

SDG: Sustainable Development Goal

SME: Small and medium-sized enterprise

SSPC: Solid state post condensation

UBA: Umweltbundesamt (German Environment Agency)

VA: Vereniging Afvalbedrijven (Dutch Waste Management Association)

WTO: World Trade Organisation

Executive summary

The bioeconomy is a new market field that was not considered when most of the existing regulations were drafted in several areas, including, for example, regulations on the end-of-life (EOL) stage of plastics. Consequentially, even though an EU bioeconomy strategy exists, a coherent and coordinated policy framework is still missing[1]. In addition, the lack of necessary mechanisms (e.g. regulative carbon pricing) and the fact that existing policies and standards are mostly based only on fossil-based products (e.g. existing EOL schemes are focused on fossil-based products and do not consider bio-based counterparts) are hampering the development of the bioeconomy.

This report contains specific proposals for regulations that are most in need of revision or demonstrate a high likelihood of adaptation with the ultimate objective of accelerating the transition to a bioeconomy. In Table 1 below, an overview of the proposed measures presented:

Table 1 Overview of identified topics and proposed measures

Identified topics	**Proposed measures**
Introduce a fossil carbon tax levied on the fossil carbon of fossil resources	Integrate a fossil carbon tax at EU level
Update of the Compostability standard	Update the standard EN 13432 on compostability in order to be in line with current practices
Develop a new policy specific for bio-based materials	Set a new policy specific for bio-based materials similar to the one existing for biofuels/bioenergy to level the playing field
	Develop a Renewable Materials Directive with binding targets, support schemes for materials using renewable carbon and mandates and bans concerning environment and health protection
Develop an effective EOL scheme	Propose a multi-component approach of which the components need to be addressed in coherence, including a.o.: design for recycling, stimulate recyclate quality rather than quantity, design standards for recyclate quality, establish independent organisation responsible for balanced life cycle impact data, base recycling targets on overall life cycle impact, establish one independent authority for EOL

With this report, the STAR4BBI project seeks to establish a supportive and coherent regulatory and standardization framework by proposing solutions to overcome existing regulatory hurdles across sectors. The aim is to stimulate investments into existing and new value chains, products and applications as well as establish a level playing field for bio-based products.

1 Introduction

In order to establish a cutting-edge bioeconomy in Europe, a well-coordinated and favourable regulatory and standardization framework is needed. Currently, a lack of necessary mechanisms (e.g. carbon pricing mechanisms) are impeding the full deployment of the bioeconomy. Several existing regulations also present challenges and their removal or update (e.g. existing EOL schemes) is considered imperative in order to support the development of a coherent bioeconomy policy.

This report provides a collection of proposed measures at different levels of the value chain to ensure a coherent bioeconomy regulatory framework. It focuses on the effects and importance of the proposals made on the future developed of bio-based industries. Figure 1 provides an overview of the selected topics and related proposals in order to tackle barriers at different levels:

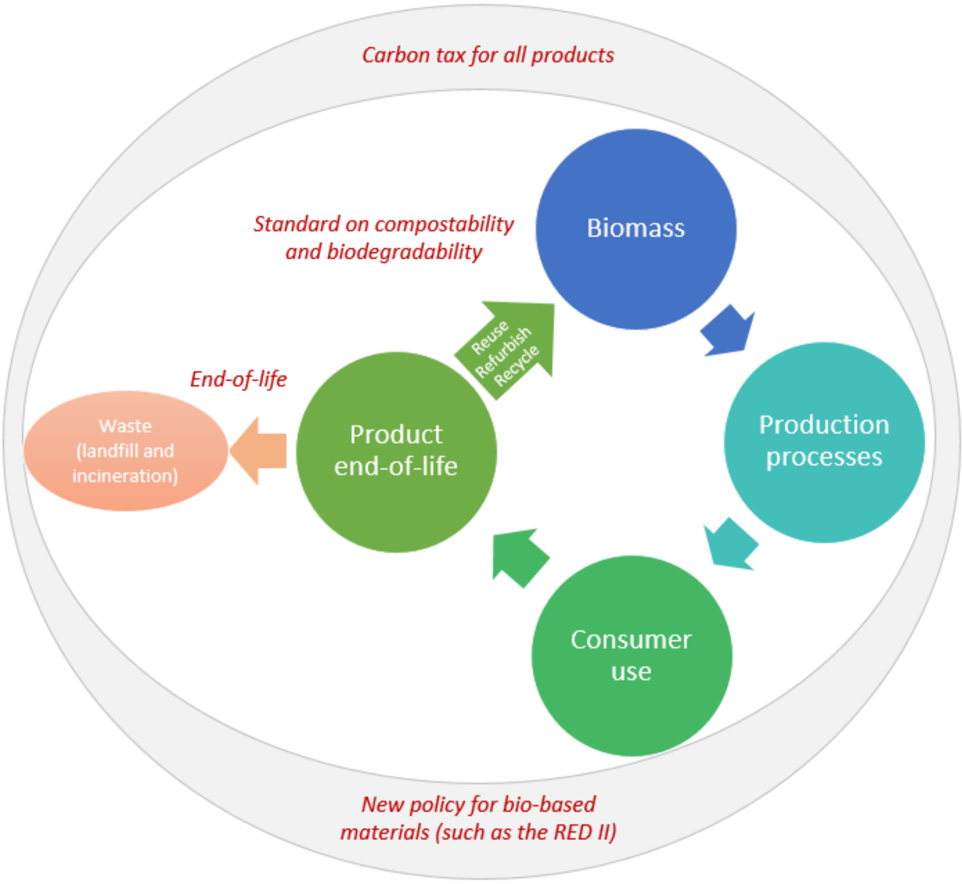

Figure 1 Selected topics that are need of revision or show the best feasibility of successful adaptation

The implementation of a **fossil carbon tax mechanism** is one of the most important measures to be considered in order to achieve a stable, supportive regulatory framework for the bioeconomy, and for ensuring a level playing field for bio-based products. A **new policy for bio-based materials**, similar to the existing renewable energy directive (RED II) for biofuels, will ensure the level playing field between bio-based products and fossil-based products and biofuels. Other proposals are focused on the EOL stage, such as the update of the **Compostability Standard** (EN 13432), as well as, the implementation of **effective EOL schemes** for bio-based plastic packaging, since they constitute a significant portion of disposable products and there is no general agreement on their preferred EOL option.

The remainder of the report is structured as follows: section 2 describes the adopted methodology and section 3 includes a general description of the topics that are in need of revision as well as related measured for improvement. More specifically, section 3.1 presents a fossil carbon tax as an alternative to a CO_2 tax, giving a comparison of both mechanisms; section 3.2 presents an evaluation of a possible update of the existing Compostability Standard; section 3.3 contains proposals to develop a new policy specific for bio-based material, similar to the existing RED II for biofuels; and section 3.4 includes specific proposals to implement effective EOL schemes for bio-based products, more specifically, for bio-based plastics. Finally, the conclusions are presented in section 4.

2 Methodology

Based on the longlist of existing challenges identified in previous tasks within the STAR4BBI project, a list of topics was selected for further development of possible measures toward the amendment of existing regulations or the development of new (European) regulations (see Figure 2). The selection criteria included, among others, the impact on the market, the feasibility of removal of a hurdle, the probability to implement the solution and the urgency. A list of previous reports that have served as a basis for developing the present document is presented below:

- Deliverable 2.1 Market entry barriers report[2]
- Deliverable 2.2 Elimination of hurdles in standards and regulation[3]
- Deliverable 3.1 Identification of technological trends in selected value chains[4]
- Deliverable 3.2 Regulatory and Standardization needs in bio-based industry[5]

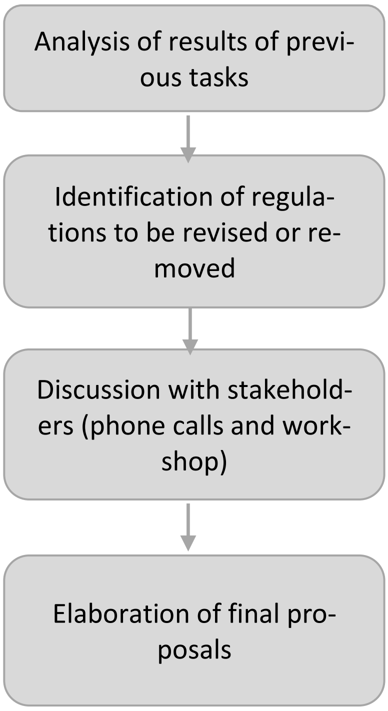

Figure 2 Methodology

By considering previous results, initial proposals for amendments of existing regulations and development of new regulations were drafted and relevant stakeholders were contacted to understand their opinion on the proposed solutions. In addition, draft proposals were discussed with experts in the field at the public workshop: "Assessing Bio-based Product Value Chains. How Better Regulation and Standardisation Can Promote a Level Playing Field" held in Cologne in May 2019.

Final proposals were drawn up based on the collected input, and individual stakeholders were contacted for further feedback and to check the feasibility for the implementation of the proposals.

3 Regulations to be amended*Fossil carbon tax levied on the fossil carbon of fossil resources*

In Deliverable 3.3 of the STAR4BBI project, the implementation of a fossil carbon tax has been suggested as a strong mechanism for evening out the scales between fossil-based and bio-based products. At the same time, a fossil carbon tax incentivizes renewable carbon utilization as part of a future circular economy. In this report, implementation mechanisms of such a tax will be discussed as well as the issues to be considered for its integration. Although the STAR4BBI project focuses on the effects and importance of the proposals made on the bio-based industries, such a tax will also have certain effects on the overall industrial activities in the EU. Therefore, by drafting our proposals, it is important to look at the overall effects of the mechanism proposed, to be able to evaluate the feasibility, effectiveness and complexity of the suggested actions.

Additionally, it is important to understand the political motivation for the recent discussions concerning the introduction of a carbon tax. The overarching political goal for the implementation of this mechanism is to achieve reductions of greenhouse gas (GHG) emissions and reach the EU and global climate targets. The mechanism proposed in STAR4BBI not only supports the bio-based economy (which is the core objective of Star4BBI), but most importantly takes into account the overarching political objective of climate protection.

In this section, implementation mechanisms for two mechanisms; fossil carbon tax and a CO_2 tax will be described in detail and a comparison between these two mechanisms will be drawn in order to evaluate the strengths and weaknesses of each of these mechanisms.

3.1.1 Fossil carbon tax vs a CO2 tax

An active discussion concerning the integration of a CO_2 tax has been taking place in a number of EU Member States (MS), considering that this mechanism will largely reduce the CO_2 emissions and help the MS reach their climate goals. The tax that is often discussed would be levied on the CO_2 emissions of products and fuels, in other words targeting the downstream emissions of the products. However, if such a tax is to be implemented, then a border carbon adjustment will be necessary for imported products to create a level playing field between the local and imported products, as otherwise the imported products will have a considerable price advantage in the EU and create unfavorable market conditions for the local producers [6].

To implement the border carbon adjustment, all imported products will need to declare their CO_2 emissions, which then can be taxed. This means that all imported products will need to carry out a life cycle assessment LCA study, to provide validated data on the CO_2 emissions of the imported product (similarly products produced in the EU will need an LCA study so that the tax will be applied on these emissions). LCA studies are expensive, time consuming and if made mandatory, a heavy financial burden especially for SMEs.

Not implementing a border carbon adjustment while a CO_2 tax is applied in the EU, will lead EU industries to relocate to other regions where such a tax is not applicable.

Instead of a CO_2 tax, better implementation mechanisms are provided by the establishment of an alternative fossil carbon tax, which can be levied on the fossil carbon contained in fossil resources, such as coal, crude oil, gas, etc. The fossil carbon tax will be levied at the extraction point of the fossil resources or, in case of import, at the EU border customs. Significant advantages of this mechanism are; (a) taxing all fossil resources from the very beginning will automatically cover the taxation throughout the complete value chain, either their use for energy purposes or for the production of products; (b) border carbon adjustment can be implemented simpler than for a CO_2 tax, since radiocarbon dating (based on the measurements of ^{14}C isotopes contained in the products) will allow to measure and tax the fossil carbon of imported products at the EU border customs. Similarly, for exported products the tax can be reimbursed to exporters according to the fossil carbon content of the exported products.

CO_2 emissions released by fossil resources are proportional to their carbon content. Therefore, by putting a tax on the carbon content of fossil resources, their emissions are expected to similarly decrease as in the case of a CO_2 tax. Additionally, this mechanism will allow taxing the fossil carbon imported into the EU, by influencing the importers of goods into the EU to take the responsibility for the fossil resources used for the production of their products.

To understand what the implementation of a CO_2 tax or the fossil carbon tax would look like the subchapters a and b analyze the implementation tools for both taxes. Subchapter a focuses on what the taxation under a CO_2 tax would look like, while the subchapter b looks at implementation mechanisms of a fossil carbon tax. Some of the central issues that both taxes would need to fulfil are listed below. The same issues or aspects to be considered (e.g. a.ii. and b.ii.) have been analysed for both taxing mechanisms. This allows to make a comparison between the two taxes in terms of better implementation tools. The overall picture of the comparison is given in the Table 5.

a. Implementation mechanisms of a CO_2 tax

a.i. Tax on CO_2 emissions

The tax that is largely discussed and has already been implemented by a number of EU countries is levied on the CO_2 emissions (downstream) of fossil fuels used by various sectors, as illustrated in Table 2 for the case of France.

a.ii. Feasibility of taxing the fossil resources used in products

As the tax is applied only on emissions from fossil fuels (downstream of the value chain) the use of fossil resources in products is not being taxed. For being able to implement a CO_2 tax on products, all products will need an LCA, to determine their CO_2 emissions, which will be taxed accordingly. LCA studies are expensive, require large efforts and a long time.

Additionally, if a product was recycled, it would be hard to design a mechanism that allows the reimbursement of the emission tax paid by the first product producer. An accurate calculation of the amount of recycled materials would need to be carried out which would enable the reimbursement of the CO_2 tax for the recycled amount of material. Even if the products are designed to be recycled, no guarantee can be given which EOL the products will actually have. These issues will create a complex situation for the recycling of materials under such taxation mechanism.

a.iii. Calculation of CO_2 emissions

The calculation of the CO_2 emissions can be done in two ways. For example, in the framework of EU Emissions Trading System (ETS) the two emission calculation methodologies are given as follows[7]:

- Under the standard methodology, emission factors are used for specific fuel types for calculating their emissions. The emission factors taken in EU ETS system are based on the values given by the Intergovernmental Panel on Climate Change (IPCC). However, for example, Germany has set its own system to calculate the emission factors for various fossil fuels that are used in Germany. These emission factors are used for calculating the national CO_2 emissions from fossil fuels in Germany and for reporting these to the European Union and the United Nations[8].

- The second method for emission calculation under the EU ETS system is using the mass balance methodology, by using the carbon content of the fuel used.

The calculation of the CO_2 emissions based on the standard methodology is complex and already existing different emission factors create more complexity to lay down a harmonized CO_2 calculation system.

The MS already implementing a CO_2 tax usually tax the emissions based on the carbon content of the fossil fuels, which is a simpler procedure for the calculation of emissions.

a.iv. Examples of implementation of taxing in the EU countries

In the EU the following countries have already implemented a CO_2 tax: Denmark, Finland, France, Ireland, Sweden, United Kingdom. Below are examples for taxation systems in France, Ireland and Sweden from the OECD database from the year of 2014.

Table 2 Share of emissions priced and average price signals from tax & ETS, France[9]

	CO_2 emissions by sector (in t CO_2)	Tax		ETS		Overlap of tax and ETS[5]	Emissions not priced by tax or ETS
		Average price (in EUR/tCO_2)	Share of emissions priced	Average price (in EUR/tCO_2)	Share of emissions priced		
Agriculture & Fishing	11 394	24.4	89%	7.2	0%	0%	11%
Electricity	27 113	12.4	100%	7.2	96%	96%	0%
Industry	102 676	8.3	55%	7.2	59%	36%	22%
Offroad transport	4 798	21.3	11%	7.2	60%	7%	35%
Residential & Commercial	114 853	18.7	38%	7.2	1%	0%	62%
Road transport	127 112	180.2	100%	0.0	0%	0%	0%
Total[4]	**387 945**	**63.7**	**68%**	**1.7**	**23%**	**17%**	**25%**

Table 3 Share of emissions priced and average price signals from tax & ETS, Ireland[10]

	CO_2 emissions by sector (in t CO_2)	Tax		ETS		Overlap of tax and ETS[5]	Emissions not priced by tax or ETS
		Average price (in EUR/tCO_2)	Share of emissions priced	Average price (in EUR/tCO_2)	Share of emissions priced		
Agriculture & Fishing	600	182.5	100%	0.0	0%	0%	0%
Electricity	12 135	2.3	95%	7.2	96%	95%	4%
Industry	6 228	33.9	65%	7.2	60%	49%	24%
Offroad transport	216	176.8	60%	7.2	16%	9%	34%
Residential & Commercial	8 363	25.3	74%	7.2	0%	0%	26%
Road transport	10 368	210.6	100%	0.0	0%	0%	0%
Total[4]	**37 910**	**69.6**	**87%**	**3.0**	**41%**	**39%**	**11%**

Table 4 Share of emissions priced and average price signals from tax & ETS, Sweden[11]

	CO_2 emissions by sector (in t CO_2)	Tax		ETS		Overlap of tax and ETS[5]	Emissions not priced by tax or ETS
		Average price (in EUR/tCO_2)	Share of emissions priced	Average price (in EUR/tCO_2)	Share of emissions priced		
Agriculture & Fishing	1 501	77.4	33%	0.0	0%	0%	67%
Electricity	5 246	193.1	100%	7.2	24%	24%	0%
Industry	60 176	62.2	24%	7.2	23%	14%	67%
Offroad transport	719	112.4	10%	7.2	68%	7%	29%
Residential & Commercial	7 484	159.4	21%	7.2	0%	0%	79%
Road transport	21 241	226.6	91%	0.0	0%	0%	9%
Total[4]	**96 367**	**68.3**	**42%**	**1.2**	**16%**	**10%**	**51%**

The Tables 2, 3 and 4, show that the rates of CO_2 tax vary for six different sectors: agriculture and fishing, electricity, industry, off-road transport, residential & commercial and road transport, see column "Average price".

The next column named "share of emissions priced" illustrates that from each of the sectors only a certain percentage of the emissions is being taxed. The same refers to the emissions priced under ETS system, only a share of these emissions within each of the sectors are covered. Looking at the "Overlap of tax and ETS" it is clear that in some sectors, there is an overlap of pricing a certain amount of emissions under both the CO_2 tax and the EU ETS system. Finally, the column "Emissions not priced by tax or ETS" shows that a considerable fraction of emissions is not being priced neither by the CO_2 tax nor by the EU ETS.

a.v.Import / Export of products

The tax cannot be implemented for imported products, unless all the products have an LCA study attached, which would enable determining the emissions of the product and taxing those.

Same implies for the exported products: The reimbursement of paid taxes would be possible if these will have an LCA study verifying the CO_2 emissions associated with the production of these products.

Not taxing the imported products while the fossil carbon tax is implemented in the EU, will lead to a disadvantage for local product producers; the imported products will have a price advantage due to comparable lower taxes they pay.

On the other hand, not reimbursing the CO_2 tax for exporting products would make local products uncompetitive in the international markets because of high production costs (increased by the CO_2 tax).

a.vi. Achieving reduction of CO_2 emissions

By applying a tax on the CO_2 emissions, the industries are expected to optimize their processes to reduce their emissions, thus avoiding/minimizing the additional taxes. Similarly, for private citizens the products with a high CO_2 emission factor will become more expensive, thus, the consumption of these products will decline, therefore also the emissions related to production of these products will drop.

a.vii. Taxation of the emissions associated with agriculture and livestock production

Around 10% of GHG emissions in the EU are associated with farming activities and livestock production[12]. Around half of these are caused by the enteric fermentation in livestock and another big contribution to these emissions is caused by the management of agricultural soils[12]. The implementation of a CO_2 tax on the emissions from agriculture would be possible to carry out with this mechanism. However, the EU countries that are already implementing the CO_2 tax implement it only upon the fossil fuels used in farming; the tax is not implemented on the emissions from land-use and methane produced from livestock. Such examples are Sweden[13], Finland[14], France[15], etc.

a.viii. Taxation of methane (CH_4) and nitrous oxide (N_2O) emissions

The impact of methane (CH_4) on climate change is 34 times greater than CO_2 over a 100-year period[16]. Full combustion of fossil fuels does not generate methane[17]. The main sources of anthropogenic methane emissions are the oil, gas and coal industries, agriculture, landfills, etc. While the emissions are not associated with (full) combustion of fossil fuels, their production, processing, storage distribution is main cause of these emissions.[18]

Nitrous oxide (N_2O) is around 300 times more potent than CO_2 and is the third most important GHG contributing to climate change. The anthropogenic sources of N_2O are mainly related to agricultural activities of nitrogen fertilization of soils, chemical industry processes and incineration processes[19].

These emissions of methane and nitrous oxide are not being taxed by the existing CO_2 taxing mechanisms. The carbon taxes implemented by now do not consider and tax CH_4 and N_2O emissions, as the tax is levied explicitly on CO_2 emissions.

a.ix. Feasibility of the implementation according to World Trade Organisation (WTO) rules

Currently there is no clarity around a CO_2 taxation system that would consider the end-of-life emissions from materials and products. Therefore, it is not possible to evaluate if WTO rules for taxation of imported products would be respected or not.

b Implementation mechanism of a fossil carbon tax

b.i. Tax on fossil carbon of fossil resources

The fossil carbon tax will be levied on all fossil resources in proportion to their carbon content, at the very early stages of the value chain by measuring the carbon content of the fossil feedstocks:

- at the coal mine
- where the crude oil is extracted
- at the gas pipeline
- if the fossil fuels are imported, then at the EU borders a duty / tax will be paid according to the carbon content of the fuels
- if products containing fossil fuels are imported, then at the EU borders a duty / tax will be paid according to the fossil carbon content of the product (if the products contain renewable carbon[1], they have to provide proof to deduct/avoid the duty)

It is a simple, yet elegant solution as taxation of the whole value chain takes place at the beginning (upstream). Independent of the sectors in which the fossil carbon will be used in the downstream stages of the value chain, the tax will be implemented from the very beginning.

For imported products, it will be also important to integrate a taxation of the fossil energy used for the production of products that are being imported in the EU. More detailed explanation on the implementation of the fossil energy tax for imported products is given in paragraph b.v.

b.ii. Feasibility of taxing fossil resources used in products

This mechanism allows an easy implementation of taxing based on the fossil carbon content of fuels and products. In this case, not only fossil fuels used in energy production will be taxed, but all fossil resources used in all sectors, also for chemicals and products.

[1] There are three sources of renewable carbon:

- Renewable carbon from recycling of already existing plastics and other organic chemistry products (mechanical and chemical recycling).
- Renewable carbon gained from all types of biomass.
- Renewable carbon from direct CO_2 utilisation of fossil point sources (while they still exist) as well as from permanently biogenous point sources and direct air capture.

b.iii. Measuring fossil carbon

The measurement of the fossil carbon content is a simple procedure. The radioactive ^{14}C isotope in fossil fuels is depleted. Other sources of carbon contain a certain small amount of ^{14}C. Hence, by measuring carbon isotopes containing in the fuels or products, it is possible to identify if the bio-based or fossil-based carbon has been used in the products or fuels. This method is being used by various certification tests for identifying the bio-based carbon content of products.

After identifying the fossil-based fraction in the product, this will be subject to the proposed fossil carbon tax. If a product contains both fossil-based and bio-based feedstocks, only the fossil-based carbon will be taxed.

In cases when a product contains carbon obtained by the carbon capture and utilization (CCU) technology, the measurements of fossil carbon might show positive results, since the captured and utilized carbon can come from a fossil source. This could happen if for example the carbon was captured by burning fossil-based resources. Thus, the taxing authority will not be able to recognize that the carbon used in the product is coming from a renewable source (CCU). Therefore, a certification is necessary for all products that will have a renewable carbon content by using a CCU technology as a prove. In this case, the content that is coming from the renewable source will be exempt of taxation.

Similarly, if a product contains recycled fossil carbon, the test will again identify the amount of the fossil carbon in the product. A certificate must be provided to prove the recycled quantity, which will be exempt of taxation. If no certification about the CCU and recycled carbon content is provided, the complete fossil carbon containing in the product will be considered as fossil-based and will be taxed.

For bio-based products stemming from various biomass sources, the measurements will identify and show the ^{14}C isotope, by this it will be identified the amount of bio-based feedstock used in the product. Also for some bio-based feedstocks (e.g. algae metabolizing fossil carbon flue gases), the C^{14} measurement might deliver confusing results. A chain of custody certification regarding the origin of the feedstocks seems to be the only solution for such cases, similar to CCU and recycled carbon cases.

b.iv. Examples of implementation of taxing in the EU countries

This mechanism has not been applied in or outside of the EU yet. Some of the EU countries, that already implement a CO_2 tax, measure the emissions based on the carbon content of the fossil fuels (e.g. Finland and Sweden[20]). However, the tax is levied on the emissions and not the carbon content at the origin of the source.

b.v. Import / Export of products

Import: When fossil resources are imported to the EU, at the border the fossil carbon content of the fossil resource will be measured and an appropriate tax will be applied to the fossil resource. If the product contains carbon from the CCU technology or recycling, a certificate needs to be provided to dismiss the taxing on that carbon content.

Since the carbon tax will influence the prices of fossil energy in the EU, it is important to create a mechanism that will include taxation of the energy use for production of imported products. This issue might be however more complex to implement according to current WTO regulations[21]. More detailed analysis of WTO rules on border tax adjustment for energy taxes needs to be carried out for the actual implementation of the fossil carbon tax.

Export: When a product is exported, the tax that has been paid according to the fossil carbon content of the product, will be reimbursed to the producer. However, it should be noted that the fossil energy used for the production processes will be taxed and this tax cannot be reimbursed to the product producers. This will also create more motivation in using renewable energy sources for the production processes to avoid paying high prices for fossil energy.

The reimbursement of the tax according to the carbon content of a product does not contradict the principle of the fossil carbon tax. This mechanism creates a system where all the fossil carbon that exists on the EU market is taxed. When the fossil carbon leaves the EU borders the tax is not applicable anymore and when fossil carbon enters the EU market from abroad, it is directly taxed.

b.vi. Achieving CO_2 emission reductions with a fossil carbon tax

The implementation of this mechanism will drive a development towards a reduced extraction of fossil resources, and to relying more on renewable carbon sources. Thus, this mechanism will serve two objectives: Switching from extraction of fossil-based resources towards renewable resources and by this, achieving CO_2 savings due to a decline of fossil-carbon usage. CO_2 emissions are proportional to the carbon content of fossil resources. By taxing the fossil carbon, the emissions are automatically affected too.

b.vii. Taxation of the emissions associated with agriculture and livestock production

Emissions from agriculture will not be possible to tax with this mechanism, since these emissions are mainly caused by methane production from livestock and land-use change. For carrying out agricultural activities, fossil resources are used for transportation, in fertilizer production, drying of harvested corn, etc. These fossil resources used in agricultural activities will be taxed according to the carbon content of these resources.

b.viii. Taxation of methane (CH_4) and nitrous oxide (N_2O) emissions

This mechanism will not include the taxation of methane and nitrous oxide emissions, since the taxation will be focused on the fossil carbon of products.

b.ix. Feasibility of the implementation according to WTO rules

One of interviewees of the project, an expert on WTO laws, stated that “according to the WTO rules, if the tax is applied to all products equally, covering both domestic and imported goods, there is no WTO law violation. So long as the tax is applied by reference to actual carbon content of the taxed product and is applied equally to imported and domestic products on that basis, and so long as the export reimbursement does not exceed the original tax, there is no WTO law problem”. Therefore, we can note that a fossil carbon tax, as suggested in this document, does not violate the rules of WTO.

Taxation of energy, used for the production of products, is more complex, since it is an indirect input and is physically not present in the product itself, so that it can be taxed. A more detailed analysis of WTO rules is necessary to find a solution for the taxation of energy that has been used for producing a product.

Table 5 Comparison of a CO_2 and fossil carbon taxation mechanisms

	Implementation of a CO_2 tax	***Implementation of a fossil carbon tax***
Taxation system	a.i CO_2 emissions are taxed.	b.i Fossil carbon contained in fossil resources and products is taxed.
Feasibility of taxing fossil resources used in products	a.ii Only applicable if all the products have a verified LCA study.	b.ii Fossil carbon containing in the product is taxed according to its fossil carbon content, either measurable by C^{14} analysis or proven by certification of origin.
Calculation of CO_2 emissions / Measuring fossil carbon	a.iii Various methodologies exist for emission calculations. Methods applied by now for CO_2 taxation are based on the calculations of the emissions based on their carbon content.	b.iii A simple measuring system based on radiocarbon dating method or certification of origin.
Examples of implementation of taxing in the EU countries	a.iv A number of examples exist in the EU.	b.iv This mechanism has not been implemented yet, therefore there are no examples of implementation.
Import / Export of products	a.v Shows the disadvantage that for imported products the tax can be implemented only if all products have an LCA study. For export, the reimbursement of the tax to the local producer will be possible if the product has an LCA study.	b.v Shows the advantage that in the case of import and export, the taxes can be implemented or reimbursed accordingly. This allows to implement this mechanism in the EU, instead of needing global taxation.
Achieving reduction of CO_2 emissions	a.vi This mechanism will lead to the reduction of CO_2 emissions.	b.vi This mechanism will lead to the reduction of CO_2 emissions, as well as the reduced use of fossil resources.
Taxation of the emissions associated with agriculture and livestock production	a.vii The number of EU States that are already implementing a CO_2 tax do not tax the methane emissions from livestock production or the emissions coming from land changes. The fossil energy used in agriculture is however being taxed by these countries.	b.vii The mechanism does not allow for taxing the emissions from agricultural emissions related to the enteric fermentation in livestock and land-use. However, the tax will cover all fossil resources that are used in machinery, fertilizers, etc. in agriculture.
Taxation of methane (CH_4) and nitrous oxide (N_2O) emissions	a.viii The tax implemented by now is levied explicitly on CO_2 emissions, so it does not include other GHGs.	b.viii Methane and nitrous oxide emissions will not be taxed under this mechanism, since the tax is levied on fossil carbon of fossil recourses and products.

Feasibility of the implementation according to WTO rules	a.ix It is not possible to evaluate, since there is no clarity around the concept for taxation of imported and exported products.	b.ix Taxation of fossil carbon as presented in this document does not violate WTO rules. Energy taxation used for production of imported products is complex and its eligibility to WTO rules is not possible to validate at this stage of research.

3.1.2 Aspects to a fossil-carbon tax at EU level

3.1.2.1 Proposals to integrate a fossil-carbon tax at EU level

There are a number of aspects where a fossil carbon tax offers more advantageous implementation possibilities compared to a tax levied on CO_2 emissions. Therefore, our proposal is the implementation of a fossil carbon tax at the EU level.

One major issue around pricing of carbon in the EU is the importance of the border carbon adjustment. This means that if there is a price put on carbon (by either of the mechanisms) in the EU, then the products that are imported into the EU will have to pay the same price for the carbon they import. The CO_2 tax is hard to implement in this case, as an LCA study would be necessary for calculating the emissions of imported products, while the fossil carbon tax allows to measure the fossil carbon content of products easily. Thus, the tax can be implemented on the fossil carbon. The same applies to the chemicals, materials and products produced in the EU which can be taxed much easier by this mechanism and, as of yet, have not been subject to a CO_2 tax mechanism.

Furthermore, for exporting products, the local taxpayers will receive back the fossil carbon taxes they have paid. This will help them staying competitive in the international markets.

Additionally, this is a simple mechanism, as the tax will be implemented right at the beginning of the value chain (or at the border for imports), so all the fossil carbon on the market will be taxed from the beginning (upstream).

It is also important to note that the eligibility of carbon pricing to WTO regulations is of central importance. Under CO_2 tax, this issue is still unclear, while for the fossil carbon tax, according to the mechanism suggested in this document, the WTO rules would not be violated.

For the purposes of reaching international climate goals, the implementation of a global fossil carbon tax would of course create larger impacts, however the complexity of achieving a political agreement on pricing carbon at the global level requires considerable time. Therefore, it is more realistic that the EU achieves an agreement for the integration of a fossil carbon price within the MS. The mechanism of the fossil carbon tax will allow for staying competitive in international markets, which means that an EU wide tax can be implemented without waiting for a global initiative and consensus.

3.1.2.2 The carbon tax rates

The interviews carried out with the stakeholders and the desk research demonstrated that the rate of the fossil carbon tax is of central importance for its effectiveness. A number of studies have been published to show the expected effects of putting a price on carbon. As mentioned in the study by

Suphi, S, et. al. (2018)[22], there are no empirical studies that estimate the effectiveness of taxing the fossil carbon content of fuels. Therefore, as a reference, the current CO_2 taxation systems of the EU MS will be analysed, as well as number of studies that have evaluated effects of CO_2 emission taxation.

As mentioned in paragraph 2, even though the proposal of a mechanism that will lead to reduction of GHG does not fall under the STAR4BBI project scope, in case of a fossil carbon tax, the effectiveness of this mechanism in terms of CO_2 savings is the major objective from the political point of view. Therefore, in this section, the CO_2 emission reductions as a central criterion for the effectiveness of this mechanism will be discussed.

Proposals for an explicit fossil carbon price to be implemented at EU level is a complex issue and out of the STAR4BBI project scope. However, as the tax rate plays a major role for its effectiveness in terms of emission reductions, the current discussions, studies and already implemented CO_2 tax rates by the MS will be presented to propose and discuss the price range which would lead to positive effects. To determine which price range for the fossil carbon tax would be effective, it is important to set a target of emission savings that will need to be reached by the application of such a tax.

According to the EU Energy Strategy 40% emission reductions compared to the levels of 1990 must be reached[23]. According to the European Environment Agency (EEA) projections, with existing measures the reductions in 2030 will reach 30,3 %[24] which falls short of the promised 40% [25] [2].

On the other hand, IPCC calls for action to cut emissions to net-zero by 2050 to remain under the 1.5 ^{0}C degrees temperature increase. Eight MS have submitted request to reach a net-zero carbon emissions by 2050[26]. Considering the new target set by IPCC the EU goal of reaching 40% emission reduction by 2030 (compared to 1990 levels) needs to be updated and a higher reduction rate needs to be targeted. Appropriately, the instrument of fossil carbon tax to be integrated at EU level, has to consider strategies for reaching the new goal of reducing emissions by 2030 (which should be higher than 40% compared to 1990 levels) and to net-zero emissions at 2050.

At the same time, the tax should allow the MS, which rely largely on fossil resources, in terms of time and taxation rate to transform and adjust towards renewable resources.

In the study by Suphi, S. et. al. (2018)[22] the reduction of CO_2 emissions for OECD countries has been analysed, if a minimum tax rate of 45 €/ton CO_2 were to be applied on fossil fuel energy resources, in these countries. Figure 3 shows the effects that such a tax would have on the emission reductions.

[2] Under the existing measures fall as well the savings achieved by the ETS emission trading system as well as savings achieved by CO_2 taxing of the MS that are already implementing a tax on emissions.

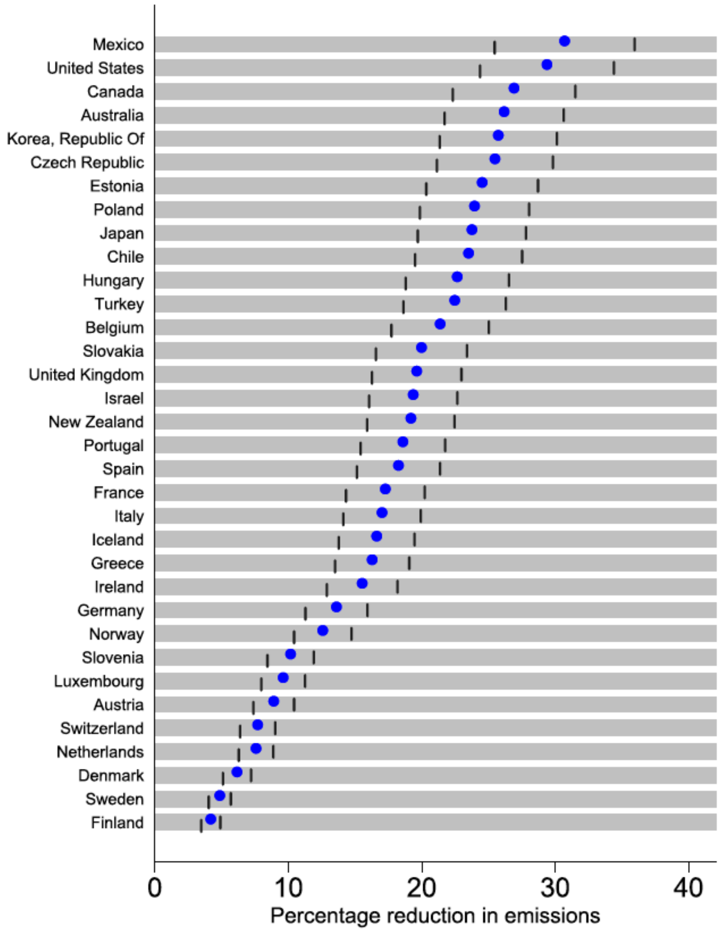

Figure 3 Implications of levying a minimum tax rate of 45 € per ton on CO_2

It is clear that for a number of countries in the EU, such as Finland, Sweden, Denmark, etc. the reductions and accordingly the economic burden will not be too heavy. In fact, the average tax rates in Finland (46,7 €/tCO_2)[30] , Sweden (68,3 €/tCO_2)[13] and Denmark (77,9 €/tCO_2)[31], according to OECD data from 2014 were higher than the proposed 45 €/ton CO_2. Even though these countries are taxing fixed percentage of emissions from different sectors at a higher price, the taxation of emissions from all fossil fuels for energy uses (suggested by the study of Sen. S, et. al. (2018)) even at a lower price would lead to more savings.

At the same time, for a number of other countries, such as Poland, Estonia, Czech Republic the tax will lead to a major cut down of their CO_2 emissions. It can be expected that the industrial landscape will accordingly change as well as the economic burden on the industries will become heavier. For example, Poland is largely dependent on coal mining, and its use for energy purposes. Pricing of carbon will therefore affect the coal mining industry with negative economic consequences[27]. Therefore, when discussing a price for carbon, the economic consequences for some of the EU countries that are largely dependent on fossil resources need to be considered, while other countries will be affected less.

The same study from Suphi, S. et. al. (2018)[22] also states that the proposed tax rate would in the long-term lead to roughly 17% emission reductions in the EU (compared to 2012, as the data used in the study were taken for the year of 2012). When looking at the target of achieving a net-zero emissions by 2050, it is clear that these 17% are not high enough. Therefore, integration of the tax and the initial minimum carbon price should allow countries with high dependence on fossil resources to have enough time for the necessary transformation. But the tax will also need to grow fast enough so that rapid reductions can be achieved.

To understand about the correlation between the emission reductions to be achieved and the price of the carbon tax, the results of Sen. S, et. al. (2018)[22] study has shown that a 1 € increase per ton of CO_2 applied on fossil energy sources reduces carbon emissions from fossil fuels by 0.73 % in a long run. This correlation factor cannot be taken as an estimation factor for the fossil carbon tax and emission reductions, as the taxation of all fossil resources would not only cover the energy sector, but all sectors where fossil resources will be used. However, this correlation factor gives an estimation on the trends between taxation rates and emission reductions if to consider only the energy sector.

The German Environment Agency (Umweltbundesamt (UBA)), has calculated that the actual costs per ton of CO_2 emissions equals to 180 €[28]. Currently the price according to EU ETS is 29.15 €/tCO_2 (on 12.07.2019), the price has been increasing in the past months[29]. The average CO_2 emission tax rates already applied by the EU MS range from 46,7 €/tCO_2 (for Finland)[30] to 77,9 €/tCO_2 (for Denmark)[31] for the year of 2014.

The range between the price rates presented above is very large. Looking at Figure 3 it is obvious that if at the price of 45 €/tCO_2 the emission reductions would be considerably high for some EU countries, then the price suggested by the UBA and even the prices that are already being implemented in the MS (as mentioned above) would have a substantial effect on some east European countries in terms of emission reductions. At the same time the rates discussed would also lead to changes in the industrial and economic landscape these countries. Therefore, we propose to set up an EU-wide minimum price at a level (which should not be less than the current EU ETS price of 29.15 €/tCO_2) that would allow the member states to adjust their economies over sufficient time. However, this minimum taxation rate has to grow relatively fast in the next years, so that the zero-net emissions recommended by IPCC become a reality by 2050. The adjustment of the taxation should be based on the EU emission reduction strategy, which in turn needs to be updated based on the most recent IPCC data. Each MS would individually decide whether to apply the minimum or a higher tax rate. Additionally, the MS can also increase the rates they adopt independently, without waiting for EU tax increases.

In order to estimate the rates of the fossil carbon tax in accordance to the CO_2 tax rates that were discussed previously, it is important to convert the discussed CO_2 tax rates into the fossil carbon tax rates.

The conversion equation is as follows:

$$\text{Fossil carbon tax} = \frac{Price\ of\ CO2\ (\frac{€}{tCO2})*M(CO2)}{M(Carbon)} = \frac{Price\ of\ CO2\ \left(\frac{€}{tCO2}\right)*44\ (g/mol)}{12\ (g/mol)}$$

Where:

$M(CO_2)$ – is the molar mass of CO_2

M(carbon) – is the molar mass of carbon

The following Table 6 shows different potential levels of a fossil carbon tax in relation to different CO_2 taxes / prices, starting from the current EU ETS rate (29.15 €/tCO_2), up to the true price proposed by the German Environment Agency (180 €/tCO_2), according to the conversion explained above. For example, at a CO_2 tax rate of 29.15 €, the corresponding price for a ton of fossil carbon needs to be 106.88 €. Accordingly, if the price for one ton of CO_2 were to be determined to be 180 €, an appropriate price for one ton of fossil carbon would be 660 €.

Table 6 Fossil carbon tax rates compared to CO_2 tax rates

CO_2 tax rate (€/tCO_2)	Corresponding fossil carbon tax rate (€/tC)
29	107
45	165
65	238
180	660

Depending on the carbon content of specific fossil resources, the fossil carbon tax rates calculated above mean different prices per ton of extracted fossil resources as demonstrated in Table 8. The exact rate of fossil carbon content contained in different fossil resources is not possible to set, since their quality varies largely and appropriately their carbon content as well. In Table 7, the given carbon contents are examples from fossil resources used in Australia.

If the mechanism of fossil carbon taxation as described in this document was implemented, then there would be no necessity to carry out calculations on the carbon content of fossil fuels, since the latter will be measured directly for each type of fossil resource. These figures given in Table 7 illustrate the approximate tax rates for a ton of each of the four different types of fuels.

Table 7 Fossil carbon content of different fossil resources

	Natural gas tC/t gas[32]	Crude oil tC/t fuel[32]	Bituminous coal tC/t fuel[32]	Lignite tC/t fuel[32]
Carbon content of fossil fuels (tC/t fuel)	0.69[33]	0.86	0.66	0.26

Table 8 Fossil carbon tax for different fossil resources

Fossil carbon tax (FCT) rate €/tC	Natural gas FCT for the given carbon content €/t gas	Crude oil FCT for the given carbon content €/t fuel	Bituminous coal FCT for the given carbon content €/t fuel	Lignite FCT for the given carbon content €/t fuel
107	74	92	71	28
165	114	142	109	43

238	164	205	157	62
660	455	568	436	172

To conclude the discussion, the following points can be mentioned:

- Pricing carbon is critical in order to achieve the climate targets. Furthermore, the price of carbon is of major significance for its effectiveness in terms of achieving emission reductions.
- A uniform carbon price has different effects for the MS. Some MS relying largely on fossil resources will be heavily affected by the tax, while for other MS the minimum price to be set at the EU will not lead to substantial carbon reductions (since these MS already a CO_2 tax in place).
- A flexible carbon price is therefore useful to avoid too heavy burdens on more susceptible countries. A minimum tax rate at EU level needs to be implemented, where individual MS can implement higher tax rates to achieve their own climate targets.
- While the introduction of the carbon tax should start at a careful, rather low level, it however has to then ramp up increasingly to reach climate targets set by the EU.
- Calculations in Table 6 provide an overview of costs to be expected for implementing the fossil carbon tax as well as how they can increase over time. Furthermore, calculations in Table 8 provide an overview of average tax rates for different types of fossil fuels and how they can increase over time.

3.1.3 Stakeholder consultation

Stakeholders have been interviewed for the validation of the mechanism suggested in the project, as well as for collecting their concerns about this taxation mechanism. The issues and questions raised around the implementation mechanism have been integrated into the proposals, to improve and refine them.

During the stakeholder workshop of the project, taking place in Cologne in May 2019, discussion around the implementation mechanisms of a fossil carbon tax took place with eight participants of the workshop. They all agreed that measuring of the carbon content of products would not be a problem and that this taxation mechanism can create a playing field both for local and imported products. During the discussion of the workshop, as well as in other interviews carried out within the project, there was no consensus as to whether the fossil carbon tax or the CO_2 tax will have an advantage in terms of implementation. However, the interviewees also agreed that the fossil carbon tax creates a much simpler opportunity for the taxation of fossil carbon in the chemicals sector, whereas a CO_2 tax would be complex to implement for this sector.

3.2 Compostability standard

Biodegradable refers to the ability of materials to break down into natural elements within a certain time after disposal. Biodegradation can occur at different conditions: Composting (elevated temperature, aerobic), anaerobic digestions, biodegradation in soil and in (marine) water. Compostability is a characteristic of a product, packaging or associated component that allows it to biodegrade under specific conditions (e.g. a certain temperature, timeframe, etc.). The compostability standard, the EN 13432 "Packaging: requirements for packaging recoverable through composting and biodegradation" is a standard developed for compostable packaging. This standard defines how quickly and to what extent a biodegradable plastic must degrade under industrial composting conditions. The EN 13432 is a harmonised European standard linked to the European Directive on Packaging and Packaging Waste (94/62/EC). The standard prescribes (among other requirements) for disintegration: after twelve weeks, at least 90% of the product should be converted to CO_2 and H_2O and the remaining material should be able to pass through a 2 x 2 mm mesh. Biodegradable product producers use this standard and certification schemes developed upon this standard to show that their products are compostable. Most biodegradable product producers do not have problems to comply with the requirements in the standard where their products will degrade within the required 12 weeks.

Industrial composters run their process in less time than the described 12 weeks in the standard. The Dutch Waste Management Association (VA) states that composting time is around 2-3 weeks and sometimes even shorter between 5 and 18 days. As a result, the compostable products might not be fully composted. On the other hand, compostable plastic producers question whether the composting cycles are long enough to fully compost the organic waste. Compost cannot be sold with visible 'non soil' parts, such as plastics, included. To avoid this problem, the composters sieve out all plastics (compostable and fossil) before the composting cycles start.[34] Compost buyers are reluctant to see any plastic (compostable or not) in their compost. Due to this reason, most compostable plastics currently end up in the incineration facilities. To both the government and the biodegradable product producers this is a less than optimal situation.

This issue was raised during the interviews with the different stakeholders.

3.2.1 Stakeholder consultation

3.2.1.1 Introduction

Research was performed on the drivers of the stakeholders. Interviews with producers and composters were conducted. These interviews were mainly with Dutch and German stakeholders. These organizations however confirmed that the issue is the same throughout the rest of Europe. They claimed that other countries are even stricter with their current policies regarding the rejection of all plastics from their streams.

3.2.1.2 Position of composters

In most biodegradable plastics there are little to none nutrients. These products will only break down to CO_2 and H_2O. This does not add any value to the end-product, the compost.

Currently the composters do not accept any compostable materials (except for the waste bags to facilitate collection of organic waste) in their composting facilities. There is a regulation set up by Rijkswaterstaat called LAP3 sector plan 6. This states that no compostable packaging according to the EN 13432 belongs in the green bin. This is the case in the Netherlands. Composters confirm that other countries within Europe are even stricter with regard to accepting compostable products (Germany, Belgium, Scandinavian countries). See Table 9 for the products that belong in the organic waste.

Table 9 List of what belongs and what does not belong in the organic waste

Yes	No
Potato peels	Ash from ashtray fireplace or barbeque
Biodegradable paper bags and compostable bi-oplastic bags with seedling logo, **if used as a collection tool for organic waste**	Glass
Flowers and house plants	Human and animal hairs
A piece of newspaper on the bottom or for wrapping fat, meat and fish scraps	Wood and thick branches
Cooked food scraps and leftovers	Hydro granules
Vegetable and fruit waste	Cat litter without an eco-label
Gravy and fat (solidified)	Fertilizer
Cheese crusts without plastic	Diapers
Cat litter with an eco-label	Milk and fruit juice packs
Christmas trees that are made small and fit in the mini container	Metals
Paper towel	Paper
Small pruning waste, foliage, mowed grass and leaves	Plastic such as bags and pedal bin bags
Coffee grounds, coffee filter, coffee pads, tea leaves and tea bags	Dog and cat shit
Corks	Potting soil with expanded clay pellets or sand
Manure from small pets such as guinea pigs and rabbits	Cigarette butts
Old bread	Offal / dead (domestic) animals
Plant pots of organic material	Stone and porcelain
Garden and potting soil	Vacuum cleaner bags and their contents
Fish and meat scraps, including bones, shells, nutshells and eggshells	Plastic tea bags
	Birdcage sand

	Bioplastic packaging (with or without the seed-ling logo)
	Sand and soil

3.2.1.3 Position of compostable products producers labelled with an EN 13432 label for industrial compostability

Compostable product producers that have an EN 13432 label want their product to be composted. Compostable product producers believe that they offer a solution for the current waste challenges.

Several compostable product producers have combined efforts to conduct research into solution routes for compostable products. They are looking into possible product groups that could be accepted by compositing facilities. The producers are aware that it will be difficult to have an agreement with the composters where all EN 13432 certified products are accepted in the composting facilities. The goal is to have product groups with co-benefits accepted. Compostable products that bring co-benefits for composters, for example additional organic waste, will then be accepted. Examples are coffee cups, tea bags and cucumber wraps. In these cases, the products will bring additional organic waste for the compost, which brings an incentive for composters to take on the biodegradable products

3.2.2 Possible solution routes

Throughout the project, several potential solutions to solve this problem were identified:

- Find a middle ground that is acceptable for all parties concerned. For this solution, the composters and the compostable products producers come to an agreement on the amount and length of cycles. This could also mean that some compostable products will be excluded as they possibly cannot compost within the proposed time. This could result in different classes within compostability (e.g. gold, silver and bronze). This would mean however further complication of certification schemes. The segregation between certain products could cause unclarity among compostable product producers, composters, consumers, certifying bodies and other parties concerned (see §3.2.5).
- Composters should run an extra cycle for materials that have not yet composted in the (first) cycle. The claim is however that composters already run additional cycles for certain products (e.g. banana peel, wooden sticks).
- Compostable product producers should change their products to comply with the 'shorter 'composting' cycles of the composters. Actually, in these cases the process is not composting anymore, however, biological drying. This means that the compostable plastics will have to be composted in less time than the previously agreed terms in the standard (12 weeks). According to several compostable product producers they are able to produce biodegradable products that compost within 6 weeks. The 12 weeks in the standard is a historical result when the thickest part of the packaging product was tested. Producers are targeting their plastic to the 12 weeks at the maximum thickness as the test is expensive and then they can certify their plastic for a broader range of applications. Most parts of the certified packaging will degrade faster than the 12 weeks. However, shortening the time further could in some cases reduce other quality characteristics of the product. Currently the biodegradable

plastic producers do not have an incentive to target at lower limits. For products to degrade fast in an industrial composting facility Polylactic acid (PLA) can be used.

- Agree on certain product groups with co-benefits that can be accepted by the composting facilities. Compostable products that bring co-benefits for composters – for example additional organic waste – will be accepted. Examples are coffee cups, tea bags, organic waste collection bags and plant pots. In these cases, the products will bring additional organic waste for the compost which brings an incentive for composters to take on the biodegradable products. Currently in The Netherlands, the VA together with BioHolland are undertaking tests with five potential product groups made of compostable materials. In the end, the use of compostable materials for such products should be mandated by the (European) government to avoid confusion among consumers.
- Change the economics of the composters. Composters currently receive a "gatefee" when they accept waste in their facilities. Increasing this fee for compostable products might increase the willingness of composters to take on these products.
- Separate collection of compostable products could lead to large enough volumes to have separate composting cycles. However, the best solution could also be biogas production. An LCA should in these cases result in the optimal route.

3.2.3 General; conclusions and recommended solution route

The compostability of compostable products is heavily debated at the moment. The composters and the biodegradable products producers are on opposite sites. All certified products labelled with the EN 13432 are currently exempted from the composting facilities (except for the compostable bags to facilitate collection of organic waste).

The project partners of STAR4BBI recommend to agree on certain product groups with co-benefits that should be accepted by the composting facilities. To have the desired result this should happen in cooperation with the government to make these product groups mandatory compostable. Examples are coffee cups, tea bags and plant pots. In these cases, the products will bring additional organic waste for the compost which brings an incentive for composters to take on the biodegradable products. Further research on specific products is currently undertaken by a combination of composters, bio-based product producers and policy makers.

3.2.4 Further recommendations related to composting of plastics

Besides the co-benefits, the selection of specific product groups could also depend on the waste that can currently be found in the compost. This is the same approach as the European Commission took with the single used plastics. They identified the top 10 products that end up in the ocean and these are now banned. With the identification of these products conclusions and recommendation can be made of which product groups shall be produced from compostable materials. The EOL route for a product should in any case be based on an LCA.

Further research should also be performed to get a clear overview of the additional advantages of combining the different streams. Supposable, in some cases composters fear the amount of nitrogen in their feedstock. They therefore need to add more carbon in the composting process. This carbon could be provided by the compostable products. Linked to this is further research in to the micro-organism portfolio of composters to investigate where micro- organism could support the improvement of the compost and where compostable products could play a role in providing for these organisms.

Communication towards end consumers will be crucial with any route taken. Communication could be supported by a labelling system with clear colours. A colour for the end-of -life solution. For this to work optimal, municipalities should also strive to standardize their collection systems.

3.2.5 Conclusion for the standard

The conclusion from the research and interviews is that changing the standard is not the solution for the current market situation. The composters do not accept any compostable plastics in their composting facilities. The opposition of composters to biodegradable products does not depend on the standard as such as they do not accept any compostable products. The standard should however be in line with the current practise. The standard was developed in 2000. As composting processes have changed considerable over the last years a revision of the standard is recommended. The goal is to come to an agreement which matches the industrial practices of today and the near future with what can be achieved for compostable plastics for products for which composting may have benefits. The standard is not yet in the review phase. However, any country can propose to start the revision.

The EC is however working on guidelines for EOL options. These guidelines also refer to the EN 13432 standard. In this way it is recommended that the standard should be changed towards the most optimal cycle length. It is necessary that all relevant stakeholders are involved in the process (including the composters, recyclers, farmers) and reach consensus.

3.3 New policy specific for bio-based materials

In order to level the playing field between bio-based products and fossil-based products and biofuels, one possibility is to introduce a policy framework for bio-based materials similar to the one existing for biofuels and bioenergy (RED and RED II35). Currently biofuels and bioenergy are strongly supported. Such government intervention has increased market shares for biofuels and similarly it is expected to stimulate an increase in demand and subsequently production of bio-based materials.

Support for bio-based materials so far has been limited to research and development. In the existing EU regulatory framework, while Member States are encouraged to promote the use of bio-based recyclable products and bio-based compostable products and their contribution to a circular economy are recognized, concrete legislative measures stimulating their use and improving market conditions for such products are still missing.

A new political framework is therefore needed to balance the support for energy and material use and allow fair allocation of biomass between the different applications. The current framework results in higher value added and higher job value creation opportunities to be missed. Therefore the new political framework should be linked with the GHG reduction, circular economy, resource efficiency and employment. In this way benefits in all three sustainability pillars (environmental, economic and social) can be achieved. When with support sufficient market establishment is achieved, this will give bio-based products the ability to compete with fossil-based products without support. For this to happen, a directive is required to create market pull for bio-based products.

A Renewable Materials Directive with specific targets and mandates for bio-based products will accelerate the transition from fossil-based materials to bio-based alternatives which has been considerably slow so far.

3.3.1 Proposals for new directive

The policy should cover bio-based materials at different stages of technology development. Fossil-based products have had years to optimize their supply chains and additionally the factories have been amortised. Policies need to trigger development of sustainable bio-based alternatives. As processes are further optimized, more resource efficiency can be attained. Accordingly, ambitious GHG reduction targets can be reached and costs can be lowered so that bio-based products become able to compete with the well-established fossil-based products.

Within the policies, support for bio-based products should be given based on how they can present solution to the environmental and societal challenges faced today. Legislation based on these motives will create a positive image for the bioeconomy and encourage investment. This is essential for establishing a market for bio-based products. Production of bio-based materials could be stimulated with targets/mandates with the goal to support ones with better environmental performance (i.e. higher GHG reduction, higher efficiency, favourable EOL option).

Environmental performance data of fossil-based and bio-based products are therefore needed for policy making. This calls for harmonised LCA procedures. The EC's Product Environmental Footprint (PEF) Initiative provides a standardised framework for the assessment of the environmental footprint of products in the European Union. Aim of PEF is to ensure that the same assumptions and calculations are made to support comparability of environmental performance claims across products delivering the same function.

It is stated in the EU Strategy for Plastics in the Circular Economy that the Commission will identify with LCA applications where the use of biodegradable or compostable plastics have clear environmental benefits. In those cases the Commission will "consider measures to stimulate innovation and drive market developments". It is acknowledged that the increasing uptake of bio-based feedstocks used in plastic production can help decrease dependency on fossil fuels. However, it is stated that support will be provided according to solid evidence that they are more sustainable compared to the non-renewable alternatives. To that effect, the Commission has started work on understanding the lifecycle impacts of bio-based plastics.

In this context, the Joint Research Centre (JRC) was entrusted by the Directorate-General for Internal market, Industry, Entrepreneurship and SMEs (DG GROW) with the project "Environmental sustainability assessment comparing through the means of lifecycle assessment the potential environmental impacts of the use of alternative feedstocks (biomass, recycled plastics, CO_2) for plastic articles in comparison to using current feedstocks (oil and gas)". JRC formed a JRC-LCA4Plastics Team and developed a draft method to conduct comparative LCAs for plastics produced from different feedstock and tested it on five screening LCA case studies. Draft project outputs were made available to stakeholders for comments in a public consultation process during November and December 2018. Box 1 highlights the major concerns of STAR4BBI project partners and bioplastic producers (members of European Bioplastics Association) over the methodology and the results of five screening case studies. It also provides changes proposed by STAR4BBI partners. JRC declared that received inputs during stakeholder consultation will be carefully assessed and will be taken into account to steer the project towards the development of a final version of the method and its application to 10 “full” LCA case studies. In March 2019, a new call was announced to give stakeholders the opportunity to provide relevant lifecycle data and technical information till end July 2019 that can help to properly and consistently develop the 10 LCA case studies and to provide comments on the suggested scenarios. No further consultation steps are foreseen in the framework of the project. Once the results of the 10 LCA case studies are available they will be made public. The 10 selected articles for LCA are: beverage bottles, food trays, flexible food packaging films, wipes, chairs, automotive interior panel, mulch films, pots, insulation boards and printer housing panel.

European Bioplastics Association is questioning the idea to base political decisions solely on LCA and states it should further consider economic and social factors. Fittingly, STAR-ProBio project is currently working on adopting life-cycle methodologies to develop an approach to measure environmental, techno-economic and social impacts, and comprehensively assess bio-based products.

Box 1. Comments on project "Comparative Life-Cycle Assessment of alternative feedstock for plastics production" reported during technical consultation process in Nov-Dec 2018

The two draft reports (one on methodology and other on the preliminary results of 5 screening case studies) were made available for technical consultation during November and December 2018. The reports raised major concerns especially among others the members of European Bioplastics Association. They raised their fear that if the study is continued as is, it could harm and decrease the market uptake of bio-based products.

One of the major concerns is regarding the accounting for biogenic carbon. The study considers both uptake and release of biogenic CO_2 as 0. This is what is done for biofuels but cannot be applied for bio-based plastics. For fuels it is simple; they are produced and then incinerated totally. For bio-products the situation is more complicated. The carbon is stored in the product for a long term and then can flow into other products by recycling. Therefore, what we propose is, the full carbon cycle is accounted across the different life cycle stages. The carbon sequestration needs to be calculated and given as credit. The embedded carbon released at the end of life stage into the atmosphere then needs to be accounted. It can be released in the form of CO_2 or in form of CO and CH_4 which have different characterization factors to calculate climate impact. Or it can be stored by mechanical or organic recycling. Therefore it is vital that the biogenic carbon is accounted over the whole life-cycle.

Another major concern is that there are currently very few bio-based plastic products which only recently entered the market and they are being compared with fossil based plastics which are at the highest level of maturity. The potential of further development of bio-based plastics regarding feedstock, agricultural practices, production and EOL, is not addressed in this study. As fossil-based technology is mature, and bio-based production is in its infancy, there is vast scope for improvements in the environmental performance of bio-based products that should not be disregarded. To have a fair comparison of bio-based and fossil-based products this impact of maturing of technology should be taken into consideration. However, in this study for example experimental data for PEF are used for comparing with very mature industrial fossil-based plastics. Instead, what we propose is, the energy efficiency and yield improvements achieved for the existing fossil-based polymers should be investigated and such improvements should be considered for bio-based polymers when making comparison.

Furthermore, there is a non-level playing field between the sources of data used in assessment of fossil vs bio-based plastics. For fossil-based plastics, PlasticsEurope provides an aggregated database representing European industry averages with data collected from numerous production sites. For bio-based plastics, such database does not exist, instead data from specific producers are used. In the study, therefore, an individual company data for bio-based plastics are compared with industry average data of fossil-based plastics. Instead, what we propose is that JRC collects data and make such an industry average also for bio-based plastics.

Additionally, the PlasticsEurope eco-profiles used for fossil-based plastics have several shortcomings. They are published with relatively long intervals (more than 5 years). Furthermore, these aggregate data constitute a “black-box” enabling no transparency into the activity data used. Environmental Product Declarations only provide information in very general terms. One point here is for example different allocation methods (physical (mass, exergy, etc.) and economic allocation) may be used when establishing an eco-profile by PlasticsEurope. However, to make a proper comparison with bio-based products the same allocation methodology needs to be applied. Otherwise, the conclusions can be misleading.

Another point is datasets from PlasticsEurope in some cases do not comply with the requirements defined in the ILCD methodology recommended by JRC. Therefore, we propose that, JRC should critically review the data used, the unit processes considered in data collection and the allocation method used by PlasticsEurope. Furthermore, have the same data quality demands for fossil-based plastics as requested for the bio-based plastics. Within the BIOSPRI[1] project, different datasets available for four fossil-based plastics were compared and significant variations were found. Especially results for impact categories ozone depletion, human toxicity (cancer and non-cancer effects), ionizing radiation, freshwater ecotoxocity, land use and abiotic depletion were found not suitable for comparison. It was pointed out to be very cautious when interpreting results obtained by different consultants for different commissioners using slightly different approaches. Furthermore, the modelling of end-of-life impact is criticized since an average scenario is used in the study involving even not pursued options. Instead, we believe showing results with the intended end-of-life option would be more logical. Then appropriate actions should be taken to steer the waste management to this ideal option.

The inclusion of indirect land use change impacts for bio-based products is also criticized. The calculation methodology for that is still highly debated. Moreover, such indirect effects are not considered for fossil-based products (effect of extraction of oil and gas on land, accidental spills, leakage from production and transportation of oil). Therefore, we believe if indirect effects are to be included, this should also be consistently done for fossil-based polymers.

1. BIOSPRI Study, Environmental impact assessments of innovative bio-based products, 2019, https://publications.europa.eu/en/publication-detail/-/publication/15bb40e3-3979-11e9-8d04-01aa75ed71a1

3.3.2 Proposals to integrate a fossil-carbon tax at EU level

3.3.2.1 Introduction

The introduction of a Renewable Materials Directive is proposed to include the linkages of renewable materials to relevant European policies, strategies, targets and goals as outlined below.

The increased use of renewable sources constitutes an important part of the package of measures needed to reduce greenhouse gas emissions and comply with the Union's commitment under the 2015 Paris Agreement on Climate Change following the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (the ‘Paris Agreement’) and with the Union 2030 Agenda and its Sustainable Development Goals (SDGs) to limit the global temperature increase to well below 2 degrees Celsius.

The increased use of renewable sources has a fundamental part to play in promoting the security of supply for energy and materials. The use of renewable sources for materials can provide alternatives to fossil-based resources. They also reduce dependence on fossil raw materials, such as crude oil, natural gas and coal. Due to rise in global population and improved standards of living, demand for materials increases. Without heightened attention to produce these materials from renewable sources, this will lead to increased use of fossil resources.

The use of renewable sources also supports the modernisation and strengthening of the EU industrial base through the creation of new value chains and industrial processes providing technological and industrial leadership as well as environmental, social and health benefits. The deployment of new and sustainable products from renewable sources will also enhance the possibility to substitute fossil raw materials in very significant parts of European industry (e.g. construction, packaging, textiles, chemicals, cosmetics, pharma ingredients, consumer goods) in line with the renewed Industrial Policy objectives[36].

Furthermore, the use of renewable sources for materials provides major opportunities for employment and regional development, especially in rural and isolated areas, in regions or territories with low population density or undergoing partial deindustrialisation. It has the potential to provide an important source of income diversification and boosting of local rural economies.[37]

The sustainable use of renewable resources for industrial purposes is set out in the Bioeconomy Strategy (update, 2018[38]). Their contribution in creating a circular, resource-efficient economy is acknowledged in the Circular Economy Action Plan[39] where it is also indicated that bio-based materials can present advantages linked to their biodegradability or compostability. Possibility to valorise residues into valuable products and cascading utilization with several reuse and recycle cycles for materials contributes to achieving the goals of the Circular Economy. The current EU policies concerning biobased products are described briefly in Annex A.

Efforts to draft a Directive may be exploited in the short term via a Commission Recommendation or Communication.

3.3.2.2 Binding overall Union target for 2050

The establishment of a binding Union renewable materials target for 2050 would encourage development of technologies, which produce materials from renewable sources and provide certainty and incentive for investors. Member States shall set their own national targets in accordance with their specific circumstances and capacity to produce materials from renewable sources following guidelines set out by the EC (as is done with RED II). They shall ensure that they collectively achieve the binding overall Union target.

A binding overall Union target for 2050 can be formulated by introducing a minimum target for share of renewable carbon (explanation see below) in the industrial production of all types of products, apart from food, feed and energy, of total carbon in the Union's gross final use in 2050.

All products that can potentially replace virgin fossil resources for products (apart from energy) shall be considered which for example includes food/feed additives.

This calls for the transition from fossil carbon to renewable sources of carbon in the chemicals, polymers and materials industries. It is important to note here that all these products require a carbon skeleton and the only alternative to using fossil is renewable carbon sources. Therefore, the use of renewable electricity as applied to replace fossil fuels in the light-duty road transport, is not an option here.

Three sources of renewable carbon can be defined[40]:

- Renewable carbon gained from all types of biomass.
- Renewable carbon from recycling of already existing plastics and other organic chemistry products (mechanical and chemical recycling).
- Renewable carbon from direct CO_2 utilisation of fossil point sources (while they still exist) as well as from permanently biogenous point sources and direct air capture.

All three are alternatives to using virgin fossil resources for carbon and all are important in ensuring no additional fossil-based carbon emission occurs into the atmosphere. In production of renewable carbon based materials of non-biological origin, special attention should be given to cover the energy demand only with renewable, non-biogenic resources.

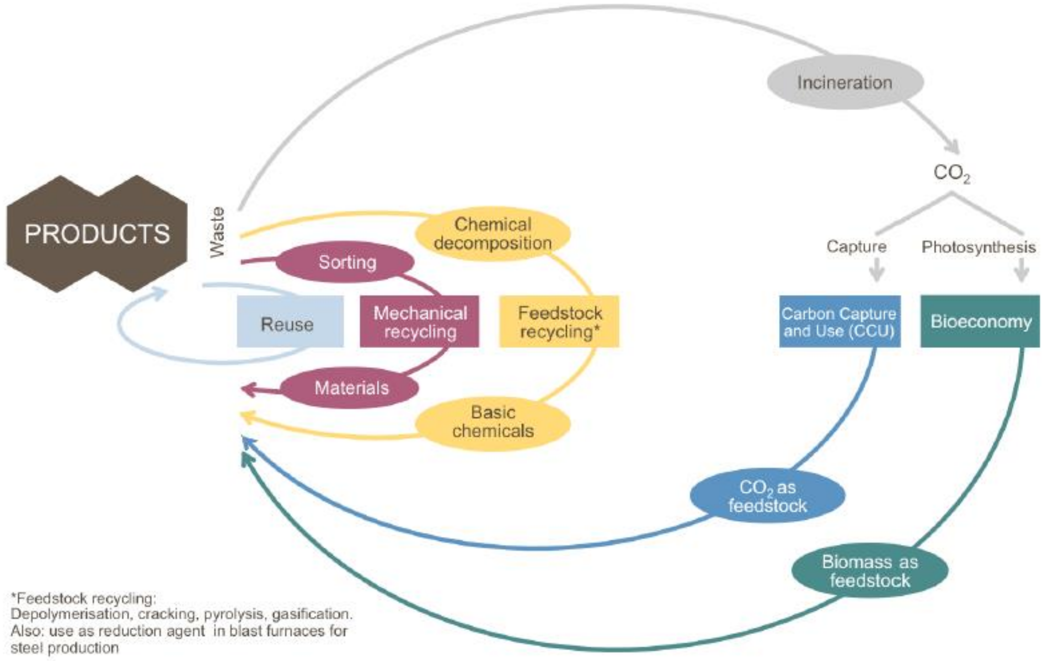

Figure 4 Renewable carbon sources: i) biomass, ii) from recycling (mechanical and chemical) and iii) direct CO_2 *utilization (Source: adapted from nova paper #10*[40]*)*

As the share of renewable carbon target for all products an indicative suggestion would be minimum 50%. The suitable % target should be determined after evaluation of the current share of renewable carbon in materials and the share that can reasonably be achieved with continued technology developments by 2050. If there are substantial cost reductions in the production of products (such as chemicals and plastics) with renewable carbon, the Commission shall assess increasing the target. Inclusion of midterm goals such as by 2030 and by 2040 can be considered.

An increased momentum can be gained from the electrification of the transport sector providing more biomass to be available for the material industry without requirement of expansion of agricultural land. Another one through the development of efficient technologies from second and third generation biomass which would not cause competition for agricultural areas. It should also be ensured that the renewable carbon sources considered do not create additional demand for land and are not expected to cause significant distortive effects on markets for raw materials, products, wastes or residues.

3.3.2.3 Mainstreaming renewable carbon sources in the chemicals and plastics sector

A separate Union target can be set specifically focusing on the sub-category of the organic chemistry and related plastics sectors. They can be considered to be key sectors in accelerating the substitution of non-renewable, virgin fossil sources. The lack of support in combination with continuously low oil prices as well as low prices for emissions trading has led to relatively slow progress in these sectors and the vast potential is not realized. The share of renewable carbon in organic chemistry products currently is about 15 %. Experts believe this share can double or even triple by 2050. [40]

Accordingly, a binding overall Union target for 2050 can be formulated along the line of:

Share of renewable carbon in the industrial production of chemicals and plastics, shall be at least 30% of total carbon in the Union's gross final use in 2050.

Inclusion of midterm goals such as by 2030 and by 2040 can be considered. Furthermore, the progress of technological development can be taken into consideration to increase the target.

The production of chemicals from direct CO_2 utilization of fossil and biogenic point sources as well as direct air capture offers interesting perspectives. Most of the technology deployment is still at a very low TRL, but first commercial plants are already being built. Carbon capture and utilisation will require large amounts of energy that need to be supplied from renewable sources such as solar radiation. Modern solar cells require much less area compared to natural photosynthesis. Experts calculated that 2% of world's desert areas would be sufficient to cover the chemical industry demand in 2050 from direct CO_2 utilization and photovoltaics. [40] Furthermore, it is chemically rather easy to turn CO_2 and H_2 into bulk chemicals and today's refinery structures utilizing fossil raw materials can be directly utilized. However, during stakeholder consultation there was a comment made regarding inclusion of direct CO_2 utilization, that the aim should be to reduce it first rather than finding energy-intensive ways to utilize it.

The stakeholders commented that it will be good to also have specific targets for other sectors to better drive the developments.

3.3.2.4 Support schemes for materials using renewable carbon

In order to support Member States' (MS) contributions to the Union target, a financial framework should be established to facilitate a transition towards increased shares of renewable carbon, in particular through the use of financial instruments, especially for the following purposes:

a) funding R&D to increase the technical feasibility and economic affordability level of renewable carbon based materials;
b) reducing the cost of capital for renewable carbon based materials projects;
c) developing projects and programmes for bringing renewable carbon based materials and plastics into the market;
d) enhancing regional cooperation among MS and between MS and third countries, through joint projects and joint support schemes.

In order to reach or exceed the Union target set, and each MS's contribution to that target set at a national level, MS may apply support schemes. Such support schemes for renewable energy have demonstrated to be very effective in fostering development, market integration and increasing shares of renewable energy. Support schemes for materials using renewable carbon shall be designed so as to maximise the integration of materials using renewable carbon in the market and to ensure that renewable carbon based materials producers are responding to market price signals and maximising their market revenues. The support granted to renewable carbon based materials projects should be implemented in a market-responsive way in order to avoid unnecessary market distortions.

The European Union and the MS should promote research, development and investment in the production of materials from renewable carbon in developing and other partner countries, thereby strengthening their environmental and economic sustainability and their export capacity of renewable carbon based materials. The imported materials produced from renewable carbon sources outside the Union can be counted towards MS' national targets.

In order to exploit full potential of biomass, the Union and the MS should promote mobilisation of existing unutilized timber and agricultural resources and the development of new production systems from these sources, provided that the sustainability criteria are met.

Additional and improved financial support for research, development and implementation of sustainable future-oriented technologies in the field of material use of biomass and CO_2 technologies is required. Furthermore, funding for R&D work in order to further develop chemical recycling to improve carbon recycling and utilization is needed.

3.3.2.5 Calculation of the share of carbon from renewable sources

It is necessary to provide clear, transparent rules for calculating the share of carbon from renewable sources (total share of biomass, recycled carbon and direct CO_2). Also the renewable carbon sources need to be defined.

The share of carbon from renewable sources shall be calculated as the gross use of carbon from renewable sources in the industrial production of all types of products, apart from food, feed and energy, divided by the gross use of carbon from all carbon sources in the industrial production of all types of products, apart from food, feed and energy, expressed as a percentage.

If the final product is made using both renewable and non-renewable carbon sources, only the part produced from renewable carbon shall be taken into account. Use of renewable carbon shall be considered only once in the final product. Meaning, the renewable carbon in the intermediate product shall not be counted in calculation of the gross use of renewable carbon. If the final product is taken after use and used as input in production of another final product (by remanufacturing, repurposing, recycling) then the renewable carbon content of this product will be considered in calculation of the gross use of renewable carbon.

Products that do not fulfil the sustainability and greenhouse gas emissions savings criteria laid down in this Renewable Materials Directive shall not be taken into account (see below). Meaning, the renewable carbon content of these products will not count towards the calculation of the gross use of carbon from renewable sources.

The producers shall make an elemental balance of their product and report the percentage of renewable carbon used in their products. Certificates and labels shall be developed to indicate the share of renewable carbon in products.

For the purpose of demonstrating to final customers the given share of carbon in the product was produced from renewable carbon sources, MS can issue guarantees of origin to producers. A guarantee of origin can be transferred from one holder to another. Double counting or double disclosure of guarantees of origin should be avoided.

Regarding implementation, one concern raised by stakeholders was how to prove it is made from renewable carbon and what percentage is made from renewable carbon. It was proposed that this could be done by calculations and reporting by the companies who are bringing the renewable carbon based materials to the market. This should be verified. It is believed that this will bring added administrative burdens and costs but will be necessary. A suggestion made by the stakeholders was to bring good communication to the consumers through labels on products such as a 5 star system with increasing star meaning a higher renewable carbon share.

3.3.2.6 Sustainability criteria for renewable carbon based materials

Renewable carbon based materials should be produced sustainably. In order to be eligible for support schemes and count towards national targets renewable carbon based materials should comply with a set of sustainability criteria.

The harmonization of the sustainability criteria for renewable carbon based materials with the criteria for biofuels and bioenergy as well as for fossil-based materials is essential. The same set of criteria that is comprehensive to cover more aspects than covered by RED and inclusion of social and economic aspects is required. Furthermore the sustainability impacts should cover the whole life-cycle and not only focus on the feedstock production. The sustainability of the manufacturing and the EOL of the product should also be considered.[41]

The sustainability criteria can be set in accordance with the European standard EN16751 Biobased products – Sustainability criteria. See also STAR4BBI report D3.3 section on Sustainability certification for all products. Reference can also be made to the STAR-ProBio project, which is currently developing a sustainability assessment framework for qualifying the sustainability of bio-based products.

Voluntary international or national certification schemes can be developed to verify compliance with the sustainability criteria set in the Renewable Materials Directive in a harmonized manner. Commission can define the adequate standards of reliability, transparency and independent auditing to be applied by the voluntary schemes.

The renewable carbon based materials should provide lower environmental impacts in comparison to using virgin fossil-based feedstocks. Setting up specific greenhouse gas emission saving targets compared to their virgin fossil-based counterparts would probably not be feasible as it is very product specific. The criteria could be set that it has lower GHG emissions and better environmental performance overall. Targets could be set for the CO_2 impact reduction from baseline values defined (for example 2 CO_2 eq. per kg defined for certain material), with 10% reduction target by 2040 and 15% reduction by 2050. This would provide incentive to further improve the environmental performance of renewable carbon based materials. This should be supported by R&D and support schemes.

Greenhouse gas emissions accounting methodology should be provided in the Renewable Materials Directive to assure application of a clear, harmonized, consistent methodology. The methodology applied for renewable energy described in RED cannot be applied for renewable materials where capture of CO_2 and emission from the fuel in use are taken to be zero. This is because after energy is produced, it is incinerated totally. Meaning the renewable carbon is completely released to the atmosphere. For renewable materials, the carbon is stored in the product for a long term and then can flow into other products by recycling. Therefore, the full carbon cycle needs to be accounted across the different life cycle stages. The carbon sequestration needs to be calculated and given as credit. The embedded carbon can be released at the end of life stage into the atmosphere that needs to be accounted. Or it may not be released and stay in the cycle by mechanical or organic recycling.

A general comment made by the stakeholders was that the “right” materials and not all should be supported. This calls for a well-defined, transparent set of sustainability criteria considering the aspects described above (see also D3.3 section on Sustainability certification for all products).

3.3.2.7 Mandates and bans concerning environmental and health protection

Mandates and bans based on environmental and health reasons will enable tapping the full positive potential of renewable carbon based materials and increase their market penetration in a long lasting way.

a. Bans against conventional materials / Mandatory use of biodegradable materials

Set specific requirements for product groups that pose significant littering problems, with a high risk of unintended disposal in nature or high difficulty in collecting from the environment. This is crucial in tackling the plastic soup issue by avoiding plastic waste and plastic micro-particles in the environment. This requires soil biodegradability for products used in soil and marine biodegradability for products used in marine water. (Note: It is important to clearly define for which materials and applications marine biodegradability is required. This property should not be requested for materials used in soil only. Preventing these materials to cause marine pollution should be tackled by improved land-based waste management. The set-up of a European standard on marine biodegradability needs to be taken forward with particular momentum, as it is one of the main barriers for introducing biodegradability as a criterion for plastic policy (see the Commission's Plastics Strategy)).

- Mandatory use of biodegradable materials in horticultural applications such as mulching films, clips, twines, silage films and carrier materials for pesticides and fertilizers
- Mandatory use of non-toxic, biodegradable lubricants and hydraulic fluids in environmentally sensitive contexts (chain saws, boats and ships, harvesting equipment)
- Mandatory use of other materials that are used in nature (e.g. plant pots, forest signs, tree protection products, golf tees)
- Ban on non-biodegradable plastic particles in cosmetics and body care products
- Mandatory use of bio-based and biodegradable materials (combination of cotton and cellulose with biodegradable plastics, absorbers and hydrogels) for hygiene articles such as wipes, diapers, tampons
- Mandatory use of biodegradable materials for fishing nets
- Mandatory use of biodegradable body bags and coffins (biodegradable plastics and biodegradable naturally reinforced composites)

Further work on identifying appropriate applications for biodegradable materials in different environments is necessary. Not all products should be designed to be biodegradable, it should be if it has added value.

b. Mandatory use of compostable materials

Use of compostable materials with food applications and bio-waste allow increased amount of separately collected bio-waste, which can be used as compost. In this way, this bio-waste does not end up in landfills where it would produce methane that is harmful to the environment or in incineration which is not efficient due to high water content of bio-waste. Alternatively, recycling of the plastics contaminated with food waste is not preferred because cleaning and recycling is water and energy intensive. Mandating these products to be made from compostable materials will also prevent non-compostable materials ending up in composting facilities. Currently consumers are not able to clearly distinguish packages made from compostable and non-compostable materials. If they will all be made from compostable materials no such problem will occur. Taking the decision out of consumer's hand will help, as confusion creates pollution as pointed out by Attero. Such regulation will enable this to be consistently applied EU wide.

- Mandatory use of compostable bio-waste bags
- Mandatory use of compostable fruit stickers
- Mandatory use of compostable plastics for coffee capsules
- Mandatory use of compostable materials for tea bags
- Mandatory use of compostable materials for wrapping packages e.g. for fruit, meat, mushrooms
- Mandatory use of compostable dishes and utensils for catering services

The single-use plastics directive[42] fails to acknowledge the potential of biodegradable and compostable plastics The single-use items are necessary in specific application to enable longer shelf-life, guarantee food hygiene and the health and safety of consumers. In a considerable number of contexts, single-use catering items are relevant, for example in closed systems with integrated waste management schemes, such as airplanes, sport arenas, or open air events. Compostable single-use products also contributes to boosting organic recycling which is one of the goals towards a sustainable circular bioeconomy.

c. <u>Ban on hormone-active plasticizers in food, cosmetics and pharmaceuticals</u>

The hormone impacting ingredients that have a long-term negative impact on the health of end consumers should be banned. They should be replaced with bio-based and if possible also biodegradable solutions.

d. <u>Increased incentive to use renewable carbon based materials in durable products</u>

This will provide environmental benefits as the carbon sequestered is stored in the product for a long time. Examples include:

- Renewable carbon based materials and composites used in the construction sector, automotive sector and consumer goods (such as furniture, tools, toys, electronics, sporting equipment)

3.3.3 Stakeholder consultation

Relevant stakeholders (including national government representatives, bio-based material producers, waste processors) were consulted in drafting this proposal through bilateral meetings as well as during the STAR4BBI workshop held in May 2019. In total 17 stakeholders were consulted. The proposal and its contents were discussed. The stakeholders were in general support of a Renewable Materials Directive. The consideration of bio-based together with recycling as a solution to replace virgin fossil resources was received very positively. It was commented that this links with the circular economy goals. The mandates that are set according to environmental concerns was seen as important in getting understanding and support of general public. Targets, mandates and bans are perceived by the stakeholders as positive instruments in bringing market pull and enabling the transition. It was pointed out that with a reliable policy support in place, industry and investors will be more inclined to invest and take the chance.

It was discussed that currently companies pursue bio-based products due to social responsibility and image, not driven by economic gains. Having such a directive is seen as very positive to support the companies in this direction. It was also mentioned that this will bring continuity as it will not be dependent on a company's marketing policy which can change over time.

The stakeholders were in general agreement that there should not be barriers against use of 1st generation feedstocks for bio-based materials as the amount of land required for making chemicals will be lower than for fuels production and at the current technology development, in environmental and economic aspects using 1st generation feedstock is preferable due to complicated conversion processes and high energy demand for producing chemicals using 2nd generation feedstock.

A warning was raised that the directive should be flexible for changes and could be adapted according to new developments. Another comment was that attention should be paid not to formulate the directive too complex. It should be a simple system, easy to implement and to control.

Another concern was about the customer perception. It should not leave room for back doors to manipulate the system. Such perverse effects were seen for RED to benefit from double counting (an example was given for the used cooking oil being not actually used). This will easily result in distrust of the public.

3.4 End-of-life (EOL)

3.4.1 Introduction

Plastic packaging constitutes a large part of the products we dispose[43]. But plastic packaging is more than just a problem which may end up in the oceans. It serves excellently to protect food and other products, increases their shelf life, reduces food spoilage and product loss. And consequently plastic brings about avoiding the footprint of producing that fraction of products which otherwise would have been spoiled or lost and could not have been consumed. Plastic packaging in many different forms is unsurpassed in this respect.

Given the fact that society will need plastic packaging in the future, current focus is on reduce, reuse and (mechanical) recycling. However, although circularity can be improved, the number of times a plastic material can be reused or mechanically recycled is limited for several reasons like polymer degradation and contamination. Also chemical recycling, being currently developed and eventually requiring even higher purity than mechanical recycling, can never keep all material in the plastics cycle. So virgin feedstock to make new plastic material is required to compensate for loss of material which cannot be recycled or reused for some reasons. And if production of plastic is to become sustainable and circular, decoupling plastic production from finite and greenhouse gas (GHG) emitting fossil resources is required and instead renewable feedstock should be used as feedstock for plastics production. This scheme is also aspired in the New Plastics Economy study by the World Economic Forum and the Ellen MacArthur Foundation[44] (Figure 5). At the same time, at present, there is no general agreement on which EOL option is most preferable for bio-based plastic packaging. Actually, bio-based and compostable plastic products face resistance from EOL parties. Composters state they fear introduction of non-compostable plastics along with compostable plastics, thus causing them troubles in making high quality compost. Recyclers say that non-drop in bio-based plastics pollute the main conventional (fossil based) recycle streams. However, although these statements may match what we can imagine, no substantiation of these claims is provided[45]. More background information on the drivers and behaviour of different stakeholders related to EOL is presented in another STAR4BBI project report 'Deliverable 2.2 Elimination of hurdles in standards and regulations' [46].

By focussing on present industrial waste processing practices and business models, solutions for EOL issues are sought in the 'old economy'. As indicated above, however, the future of plastics requires a transition toward bio-based. In the next sections, several steps to support the transition to bio-based plastics are elaborated.

Before making proposals to further support the transition to a sustainable and circular packaging loop and to overcome the hurdles that bio-based and compostable plastic packaging currently face to enter the market (section 3.4.4), first existing policies (section 3.4.2) and strategies, mechanisms and solutions addressed in literature (section 3.4.3) are reviewed and shortly discussed.

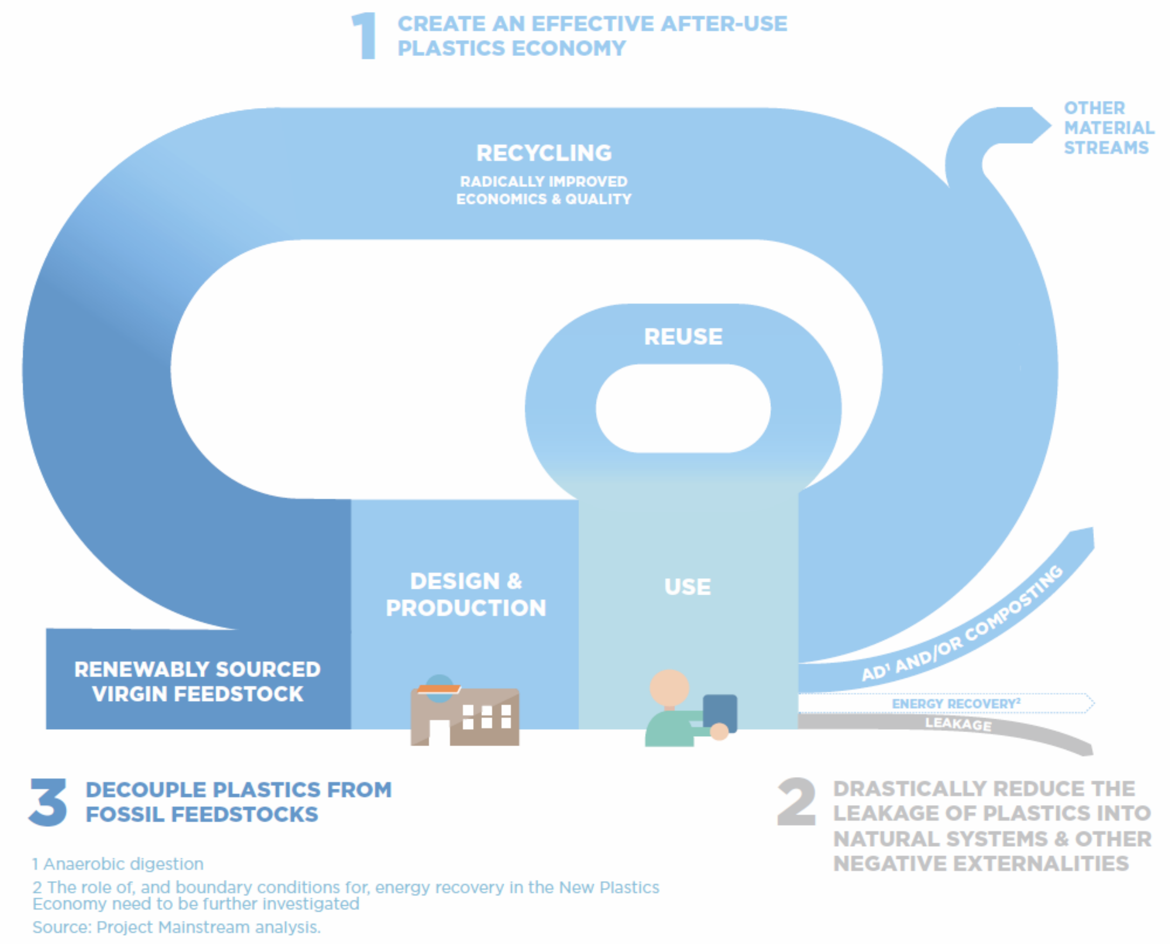

Figure 5 Ambitions of the New Plastics Economy (copied from Ellen MacArthur Foundation[44])

3.4.2 Existing policy framework on EOL

Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018, amending Directive 94/62/EC on packaging and packaging waste [47], focuses on incentives for the application of the waste hierarchy (reuse is preferred over recycling, which is preferred over incineration and landfilling) and sets specific targets for recycling. In the overview below, solid bullets show state-ments, rules and targets specified in the Directive, open bullets present our eventual comments:

- The targets for recovery and recycling of packaging and packaging waste are increased. The recycling target for plastics is set at 50% by weight of the plastic packaging waste brought to the market by end of 2025, 55% by end of 2030. Indirectly, a very rough indication of the quality of the recycled material is provided by requiring that "the weight of packaging waste recycled shall be calculated as the weight ... that ... enters the recycling operation whereby waste materials are actually reprocessed into products, materials or substances".

- As a result of increasing recycling targets, multi-layer packaging which cannot be recycled is under pressure. However, the environmental impact of incinerating a very thin multilayer food packaging film may be lower than recycling of a mono-material sheet which needs to be much thicker to provide the same required food preservation and protection functionality. And the environmental impact of food loss is much larger than the environmental impact of packaging. (also see paragraph on 'design for recycling' in section 3.4.4).
- As a result of the new definition for what counts as recycled material set in Directive 2018/852 and Commission Implementing Decision 2019/665[48], recycling rate in the Netherlands, where a post-consumer plastic waste collection and recycling system has been in place since 2014, has decreased from over 50% (previous definition of what counts as recycling) to 38% (new definition).
- Although the Directive speaks about "promote recycling materials of high quality" and requires that "packaging shall be designed, produced and commercialised in such a way as to permit its reuse or recovery, including recycling", no sharp specification of quality is presented. As long as externalities for fossil feedstock are not allocated in full to fossil based products, recycling will be optimised for economy instead of life-cycle impact. Depending on the specific product and plastic type DKR allows 94% purity on object level. Polymer purity, however, is often lower, around 90%, due to components adhering to the product, whereas required purity for valuable recycling is at least 96 to 98%, depending on the product.
- Clear quality specifications for recyclate materials need to be established based on plastics processing industry needs in order to make sure that different Member States (MS) come up with comparable recycle rates.

- "Measures of MS should ... aim at minimising the environmental impact of packaging and packaging waste from a life-cycle perspective, taking into account, where appropriate, the benefits of using bio-based materials and materials suitable for multiple recycling."
  - An "aim to minimise environmental impact ... from a life-cycle perspective" leaves ample space for discussion when no clear rules are set for how to quantify environmental impact. For instance, waste processors/recyclers say that recycling would benefit when only the top 3 plastic types (PE, PET, PP) would be used for packaging, and it may sound logical when not going in more detail. However, environmental impact involves more than EOL. And making the current top 3 plastics bio-based is not automatically most resource (Carbon) use efficient.
  - The same holds for multi-layer packaging which are difficult to mechanically recycle indeed. The environmental impact benefit of using such multi-layers, even when it cannot be mechanically recycled, may be expected significant (also see §3.4.4.2).
  - Bio-based materials would benefit more if sustainability and circularity criteria are more strict.
  - Overall impact of a packaging product includes the following aspects: material production (resource use efficiency), product manufacturing (design for use and recycling), functionality (protection and safety of packed product, avoid losses), recyclability and impact on human health and the environment (reuse, mechanical recycling, digestion into biogas, composting, incineration). In the end, the human

health and the environmental impact are considered more important than circularity[49].

- The amount of waste that enters aerobic (composting) or anaerobic (digestion into biogas) treatment can be counted as recycled, provided that such treatment generates output which is to be used as a recycled product or material. Further it says: In case reprocessing of biodegradable packaging into fuels or other means to generate energy, this should not be counted as recycling.
  - Biodegradable plastics in principle do not leave compost or digestate, except for a small part which contributes to the growth of the microorganisms, so composting and digestion are not (or hardly) considered recycling according to this Directive. And even if digestion into biogas would leave some digestate, it yields 'fuel or other means to generate energy', so again it is not considered recycling. Nevertheless, using compostable bags to collect (additional!) wet organic waste may avoid burning of water if such wet organic waste was otherwise disposed in the residual waste stream. Also, polyolefin (PE, PP) packaging may take up fatty acid molecules from food, which makes them less suitable for recycling[50]. Or, PET trays may get contaminated with e.g. meat of fish residuals or other sticky food, ending up in the incinerator. Making such packaging from alternative digestable bio-based materials would allow anaerobic digestion into biogas, thus offering good opportunities to minimise environmental impact in such cases.
- "Packaging waste processed for the purpose of composting shall be of such a biodegradable nature that it does not hinder ... the composting process".
  - 'Composting process' is not exactly defined. Just in the Netherlands alone there are several different industrial operation practices. Also see section 3.2.

3.4.3 Issues, messages and solutions addressed in literature

In recent years several (large) studies on EOL issues related to circularity of (bio-based) plastics as well as potential solutions have been published. The titles of the publications speak for themselves: 'A Circular Economy for Plastics – Insights from research and innovation to inform policy and funding decisions' (2019)[51], 'A European Strategy for plastics in the circular economy – Local and regional dimension' (2018)[52], 'Biobased Plastics in a Circular Economy – Policy suggestions for biobased and biodegradable plastics' (2017)[53], and 'Regulatory barriers for the Circular Economy – Lessons from ten case studies' (2016)[49], 'The New Plastics Economy – Rethinking the future of plastics' [44]. These studies show directions for solutions, but also show the complexity regarding EOL routes for packaging. In the next paragraph, solid bullets show statements from the studies, open bullets present our eventual comments:

- Create an effective after-use economy. It is crucial to capture more material value and increase resource productivity (circularity and recycling of plastics). It also provides a direct economic incentive to avoid leakage into natural systems, which is currently 32% worldwide as reported. And it will help enable the transition to renewably sourced feedstock by reducing the scale of the transition[44].
  - Creating an effective after-use economy requires specific measures.
  - Focus on after-use economy has shifted focus to mono-materials and to limiting the number of plastic types used in packaging. These are not automatically the optimal solution to make plastic packaging more sustainable and circular, being bio-based. (also §3.4.4. 2 and §3.4.4.6).

- Virgin plastics should be bio-based; decouple from fossil fuels[44].
    - Indeed, contrary to what sometimes is suggested, material can only be mechanically recycled for a limited number of times. Polymers degrade during use and subsequent thermal processing (re)cycles, and impurities negatively influence properties. Polyolefins can only be recycled once or twice. Transparent and white PE and PP based packaging may become coloured packaging, and then the last stage would be e.g. a garden chair. Polyesters like PET, PLA and PEF can be recycled several times because its molecular structure can be repaired by solid state post condensation (SSPC, also see 3.4.4.6). So materials have a finite life and virgin feedstock is required to substitute materials which can no longer serve requirements. So plastics should be based on bio-based feedstock because that is circular.
- Current plastic packaging offers great functional benefits, but it has an inherent design failure: its intended useful life is typically less than one year; however, the material persists for centuries, which is particularly damaging if it leaks outside collection systems, as happens today with 32% of plastic packaging[44].
    - So far it has been a no-go area to propose the use of plastics which degrade relatively quickly for packaging when unintentionally leaked to the environment. Littering indeed is a consumer issue, not a material issue, and fear is that consumers would intentionally litter plastic because it will degrade 'anyway'. However, depending on the type of biodegradable plastic, it may take many years before complete degradation of such plastic product is reached, thus still polluting the rivers and oceans. On the other hand, anti-littering campaigns are a recurring phenomenon, without the desired effect apparently. Next to the most important answer to littering, establishing an appropriate waste management system, now it seems that the large amount of plastics littered allows to think in parallel about developing plastic products which meet high demands during service life, but will be less harmful to the environment if unintentionally littered than non-degradable plastics.
- Lack of harmonisation of deposit systems could result in internal market disruptions in border regions. But on the other hand, it is stated: It is unlikely that a unified deposit-refund scheme at the EU level would be an efficient and relevant tool to reduce plastic littering and to increase recycling rates of plastic bottles. Deposit-refund schemes should be tailored to the specific circumstances and needs of the geographical areas they cover[52].
    - The European Waste Framework Directive (Directive 2008/98/EC, also see chapter 3.8 of STAR4BBI project report D3.3 [71]) has not led to uniform waste management systems within Europe[54]. In the US waste is predominantly land-filled and worldwide various countries and regions have no implemented waste management system at all. Still, companies produce globally and find difficulties to select what type of waste management systems their packaging products should fit. The amendment by Directive 2018/851 has made the calculation of the recycling % more complex, therefore, more rumbling with numbers may be anticipated.
- Near infrared analysis (NIR) allows separation of bio-based plastics, however, investment costs are high in relation to the small volume of streams[53].
    - This is not only true for bio-based plastics, but for all (fossil based) plastics.
- More plastic recycling is directly linked to reduction of littering and plastic debris in oceans[49].

  - It is not the recycling but implementation of sound waste management systems that link to reduction of littering. In this respect there is no difference between mechanical recycling, reuse or even incineration. An exception may be poorly implemented land-filling facilities that may cause additional littering.
- The Polyolefin Circular Economy Platform (PCEP) works on the development of packaging design guidelines and assessment protocols according to the principles of the Circular Economy, stimulation of innovation to improve recycling, conversion technologies and use[55].
  - Bio-based polyolefins would benefit from such developments. However, it is not sure yet in which applications bio-based polyolefins will show best overall environmental impact performance. Where 'overall impact' means: material production, product manufacturing, functionality during use and EOL.
- Almost 60 percent of the European plastics converting companies find it hard or very hard to get a supply of recycled plastics materials that meet their quality standards, reported the European Plastics Converters Association. Another concern is that the regulations are currently not strong enough to support use of recycled plastics in materials of higher value[56].
  - The use of recycled plastics in highest value/performing products requires quality standards. Development of EU wide quality standards for pre-sorted and sorted plastic waste, harmonisation of test methods for recycled plastic materials and certification of plastic recycling operations would help improve the quality and economics of plastics recycling.
- A step towards global standardization of recycling was recently undertaken by the Association of Plastics Recyclers and Plastics Recycling Europe when they jointly developed a global definition for the term "recyclable" as it relates to plastic packaging and products. The trade groups emphasized that a global definition of recyclability 'is an integral step to harmonize the worldwide plastics recycling industry.' The proposed definition establishes four conditions that a plastic product must meet to be considered recyclable[57]:
    - It must be made with a plastic that is collected for recycling, has market value, and/or is supported by a legislatively mandated program;
    - It must be sorted and aggregated into defined streams for recycling processes;
    - It can be processed and reclaimed/recycled with commercial recycling processes;
    - The recycled plastic becomes a raw material that is used in the production of new products.
  - These conditions are basically addressed in Directive 2018/852. Connecting quality of the plastic recyclate needs to be addressed to effectively gear towards use of recycled plastics in highest value products.
- The studies also present a range of general recommendations, mostly not elaborated in detail, for policy makers regarding EOL, of which a part focusses on present (fossil) EOL issues, and only a smaller part explicitly considers bio-based:
    - facilitate collaboration across the plastics value chain[51]
    - harmonise and enforce regulation to connect the different actors of the plastics value chain[51]
    - provide funding for innovation in products and materials[51]
    - develop incentives, such as extended producer responsibility (EPR) [51]
    - create incentives for development of materials based on renewable feedstock and recycled materials[51]

- incorporate circular design in education[51]
- gather and share reliable data on virgin and recycled material composition, sorting and recycling performance[51]
- develop harmonised standards for quality of mechanically and chemically recycled plastics, and for verification of recycled content[51]
- stimulate demand for recycled plastics, e.g. by public procurement, taking into account costs of negative externalities[51]
- introduce a set of sustainability criteria and quality criteria for certification systems[53]
- stimulate recycling systems for fossil plastics and bio-based plastics[53]
- make a plan for recycling of bio-based plastics[53]
- set specific standards regarding soil and marine biodegradability for products with a high risk of unintended littering[53]
- internalise environmental costs and value of recuperation of materials, combined with extended producer responsibility that stimulates the design for circularity[49]
- consider the whole life cycle of the packaging by e.g. LCA since these allow finding the 'hotspots' and understanding where shall the improvements be focused on[49]

The above shows that just focussing on present EOL issues may lead to small improvements, but also distracts attention from where the future of plastics is, being bio-based plastics.

3.4.4 Proposals to support transition to bio-based plastic packaging

3.4.4.1 General

EOL is a multi-component problem which needs to be addressed in coherence. Different types of initiatives need to be started/elaborated in order to tackle barriers at different levels, and to get an effective EOL scheme implemented. Actually, all these initiatives need to be in place in order to reach this goal. The different levels of barriers and appropriate proposals are the following:

- Practical barriers to be solved in view of *recycling* as EOL:
  - Stimulate 'design for recycling'
  - Create incentives to stimulate sorting quality rather than quantity
  - Design standards that regulate recyclates
- Practical barriers to be solved in view of *composting* as EOL:
  - Better standard on compostability (see § 3.2)
  - Better use of composting and anaerobic digestion processes
- Knowledge barriers to be solved in order to be able to make sustainable choices for EOL:
  - Stimulate research on the transitions towards bio-based in a circular economy
  - Base targets for reuse, composting, digestion and recycling on life cycle impact analysis
  - Establish an independent organisation responsible for clear and balanced unambiguous life cycle impact data for EOL options for products, in combination with impact data for material production, product manufacturing as well as the use phase (product functionality)
- Organisational barriers to be solved:

- Implement a coherent waste management system
- Centralize the advising authority for EOL in one organisation, and include producers, (bio and non-bio) product designers and waste processors in the decision making and in order to improve cooperation between these parties

These will be elaborated in the following paragraphs. In each paragraph, first it is indicated why a solution is required, and next the proposals to address the issues are presented.

3.4.4.2 Stimulate 'design for recycling'

Post-consumer plastic packaging waste consists of different polymer types. Recycling of plastic packaging products requires separation of these different polymer types, because a mix of different plastic types yields inferior performance. Commonly, plastic packaging separation is first performed on an object level to produce 'sorted products'. In some countries this is mainly performed using NIR, in other countries this is still often done manually. After milling and washing (the actual mechanical recycling) additional sorting techniques can be used like density separation (float sink separation) and flake sorting (NIR and/or colour) in order to achieve higher recyclate quality. Typically sorted products consist of more than one component, e.g. a flask body, a cap or closure and a label. These may be produced from different plastics types. If the Near Infrared (NIR) assisted product sorting system deposits such a product in the collection box of the main component, the polymers of the other components come along. On the other hand, the NIR could also detect the label, and deposit the entire product in the respective box[50]. And as mentioned, a mix of such different plastic types in a recyclate material yields inferior performance. Design for recycling can help to improve the polymer purity (quality) of sorter produces and this will facilitate further purifications steps and lead to increased yields of high quality in mechanical recycling.

Design for recycling could involve making different components of one packaging product from one polymer type, or by designing for effective separation of different components prior or during the sorting or washing process.

Multi-layer film products, which only constitute 4% of packaging materials[58], cannot be mechanically recycled to high value products. In response, so called mono-materials are getting attention as a solution. However, these would need to be (much) thicker to serve the purpose, and consequently it is a question to what extent the environmental impact benefit improves when using mono-materials. On the other hand, multi-layer products (trays, films) based on biodegradable polymers at EOL could be f.i. digested into biogas, thus yielding a very valuable product. Such biodegradable multi-layer products would need to be developed. Also packaging contaminated with food is difficult to mechanically recycle[49], and such packaging waste may be converted into biogas if made from anaerobically digestable plastic. Further, filled plastic products may be difficult to mechanically recycle and cause slags when incinerated. Also such products may be made digestable or compostable.

Drop-in polymers like bioPE fit perfectly in the current fossil PE recycle stream. However, recycling of PE in high value products is difficult. Moreover, the resource use efficiency to produce bioPE is significantly lower compared to polyesters like PLA (also see § 3.4.4.6). So the present operational situation does not automatically point towards the best solution for the future.

Packaging of several fresh food products (meat, fish, vegetables) tends to be contaminated with residual food at EOL. This makes these products less suitable for mechanical recycling due to uptake of smell and fatty components, in particular for polyolefin (PE, PP) based packaging products. Packaging which easily gets contaminated with (wet) organic material may be produced from biodegradable plastic. Biodegradable plastics could be digested into biogas together with other organic kitchen waste, thus obtaining a more valuable product than compost. Biodegradable plastic would fully convert to water and carbon dioxide and not yield any compost. Biogas presents a higher value than energy recovery through incineration.

If packaging products within a certain product group would be made mandatorily from one type of plastic, 'sorting errors' by both the consumer as well as at the sorting plant would be reduced. E.g. if tea bags are sometimes compostable and sometimes not, the consumer gets confused and puts non-biodegradable bags in the organic waste bin, with a high risk that the small PP fibres end up in the compost and on the land. When making all the tea bags from compostable material, it will be much more clear for consumers and waste processors to get tea bags in the desired stream. Or, if 80% of films are made from PE, avoid the use of PP films, thus reducing errors at the sorting facility. Or even: if food is particularly packed in e.g. PET, recycled PET (rPET) could be more easily used for food packaging again if PET would not be used for packaging of products that are not compatible with food. So product/packaging combinations may be looked for. Further, black colorants might be avoided as the polymer type of black products cannot be identified with NIR. Other colorants may also be avoided as much as possible because they limit mechanical recycling options; transparent and white products can be recycled in higher value applications than coloured products.

Since paper has a positive appeal to part of the consumers, initiatives to replace plastic by paper packaging are still around. Incorrect disposal is likely, and will burden the sorting and recycling operation by both plastic recyclers as well as paper recyclers. It should be avoided in any case that plastic products look like paper. And vice versa.

Ultimately, optimisation of design for recycling would involve an assessment of the entire cycle of products (also see § 3.4.4.9):

- material production: involving resource use efficiency and overall impacts for human health, climate change and ecological environment aspects
- product design: featuring functionality and EOL options
- use phase: taking into account product protection, including food safety (= human health), and reducing product loss
- EOL treatment: reuse, mechanical or chemical recycling, digestion into biogas, composting, incineration with energy (power) recovery

3.4.4.3 Create incentives to stimulate sorting quality rather than quantity

Several techniques for separation of plastic are available[59]. However, focus at present is at meeting 'recycling yield', meeting agreements with authorities with respect to for example the amount of residual waste that is allowed to be incinerated[60], and meeting the minimum DKR sorting quality. DKR requires f.i. a sorting 'purity' of 94% for PE (rigids), PS and PP at object level [61] (e.g. a bottle with cap and label). Due to components adhering to the object the polymer purity level is only about 90%. For films the main requirement is that sheets should be larger than DIN A4 size, so no specification of polymer type. However, the polymer purity is important for making high quality new products, and depending on the product this should be 95 to 98%.

Another issue is that the so called Mix fraction, which constitutes of polymers like PS and ABS, but also quite an amount of PE and PP objects like shampoo flasks and dairy produce bottles. It appears unclear why quite an amount of PE and PP items do not end up in the respective dedicated fractions[50].

Incentives should be implemented to strive for the highest quality sorted products (at a sorting facility) that are used to produce recyclates in a mechanical recycling facility. Reduction of sorting errors, typically about 10% nowadays, would require a lower throughput of the sorting facility that is presently not compensated for by the increased value of the sorted products. Improved sorting on an object level will facilitate the production of recyclates with higher purity and quality at higher yields[62].

In the Netherlands, few to no sorting obligations for plastic packaging hold for companies. They pay for disposal themselves and a majority of the plastic waste is incinerated.

3.4.4.4 Better use of composting and anaerobic digestion processes

Composting in practise is about organic waste processing rather than producing compost. The resulting driver is to increase throughput. Increasing throughput can be achieved by applying biological drying instead of a full composting cycle. This has been implemented during the past year in the Netherlands, and a similar trend, though less widespread, is observed in Germany as well. Consequently, the output is not fully composted material but dried biomass mainly. The resulting biomass cannot be used (directly) as compost as it will consume oxygen during further degradation, and a reduction of the oxygen level in the soil will negatively affect plant growth. At the same time, feedstock demand for biomass fueled power plants is increasing while demand for compost is limited. Therefore, an increasing percentage of biomass waste is incinerated for power production after biological drying.

Incineration of dried biomass is much more beneficial than incineration of wet organic waste. For conversion of wet organic waste, however, anaerobic digestion into biogas is a beneficial option. Next to bio-based digestable plastics, also contaminated paper (pizza boxes) may also be included. A sound combination of digestable materials may create required volumes to operate cost efficiently. Advantages and disadvantages of several options would need to be investigated: biogenic drying followed by incineration versus composting versus anaerobic digestion. Preferences will depend a.o. on the composition of the organic waste (viz. lignocellulose, carbohydrates, lignin, salts/ash) and its moisture content. In fact a better understanding of the potential of composting and anaerobic digestion processes for conversion of different organic waste is required.

3.4.4.5 Implement a coherent waste management system

Effective and efficient treatment of products at EOL starts with disposal by consumers which is aligned with operation practices at waste processors. When consumers have to pay for disposal of one type of waste, and not for another type, the driver to avoid costs may lead to non-compostable products ending in the organic waste bin, or non-recyclable materials ending in the plastics bin. But also collection frequency or the distance to a waste deposit location may affect consumer disposal behaviour. A risk assessment on consumer behaviour would need to be performed. In order to have the consumer cooperate at his/her best ability, any pressure on him/her should be avoided. So charging for EOL treatment should not be connected to actual disposal of products, but to the moment of purchasing the product.

At the same time, it should be clear to the consumer which packaging product goes where. And what to separate and what not. The simpler and the less exceptions, the better. For this purpose, it would largely help if all items within certain product groups are based on materials which fit well and optimally in one particular EOL route (example of tea bags in paragraph '3.4.4.2. Stimulate design for recycling'). Additionally, if recycling benefits from product parts being separated by the consumer, e.g. the lid and tray are different materials and needs to be separated for optimal recycling, separation of all products would be easiest to communicate. Consumers may also have logical automatisms which hinder recycling, e.g. pressing plastic films in a beaker to reduce volume. However, if the sorting system recognises the PP beaker, also the PE film is ending up in the PP sorting batch.

The optimal EOL route for (groups of) products would need to be based on an impact assessment. The best EOL route may be different for large cities, towns and the country side, but it does not make sense that each municipality has its own, deviating, recommendations. Preferably, both the impact assessments as well as recommendations are responsibility of independent organisations / authorities (paragraphs on '3.4.4.9. Establish independent organisation responsible for balanced life-cycle impact data' and '3.4.4.10. Centralize the advising authority for EOL').

Compostable plastics are welcomed neither by composters nor by plastic recyclers nowadays. Composters fear introduction of non-compostable plastics and related additional sorting costs, recyclers fear reduction of recyclate quality and reduced income. When sorted out, compostable plastics could be very well digested into biogas, eventually together with kitchen waste which is a good feedstock for digestion into biogas as well. This would mean that kitchen waste and garden waste would have to be collected separately.

Home composting avoids transportation of waste which might be a reasonable solution for depopulated rural areas. However, the discussion about advantages and disadvantages of home composting is not settled yet. Although a few national standards and one certification scheme on home compostability are in place, so far no European Standard is in place to define the requirements for home compostable products. Further, home-composting bears the risk of producing the strong greenhouse gas methane. And some types of kitchen waste with particularly high energy content such as meat and fish are not suitable for home-composting[63]. The environmental cost and benefit of home composting versus industrial composting, often not yet in place, needs to be quantified. A closed waste management system for all waste streams clearly has the advantage of control over what happens to waste, thus reducing risks.

Deposit-return schemes in combination with manufacturing agreements (design for recycling) are very effective. An example is the Dutch refund system for soda-bottles were design and material agreements (labels, glues, PET grades) in combination with dedicated mechanical recycling processes lead to high quality rPET[50].

It may be noted that deposit-return systems work well, but are expensive as well, in particular for shops and supermarkets. If all packaging products within one product group are made from one type of plastic, separate collection of post-consumer plastic packaging via LWP (light weight packaging = plastic, metal and drinking carton packaging) will also result in improved sorting purity and quality, and consequently good recycling quality[50].

Harmonisation of waste management systems across Europe, taking into account different circumstances at large cities, towns and the country side, is needed to give material and product manufacturers a clear framework for design for recycling. Such harmonisation would require involvement of important stakeholders: material producers, product manufacturers and waste processors. And as mentioned, consumer behaviour and overall impact should be included as well. As an example, in the Dutch 'Implementation program Circular Economy 2019-2023', government, bio-based plastics producers and waste processors are discussing an action plan on how to get to higher share of sustainably produced bio-based plastics[64]. Another example is the region of Frankfurt am Main (D) where the same type of stakeholders are discussing similar action plans[65].

As a minor aspect as part of such harmonisation, it would help if bins for different types of waste would have the same colours throughout Europe; bins for organic waste f.i. are green in the Netherlands and Belgium, and brown in most regions of Germany. In Germany a green bin may be used for green glass, paper and organic waste, depending on the municipality[66]. In Paris, a green container is also used for residual waste[67].

3.4.4.6 Stimulate research on the transitions towards bio-based in a circular economy

Separation of post-consumer plastic packaging waste will never be 100%, and polymer mixtures generally have reduced properties as compared to virgin materials. As a reaction various stakeholders ask to limit the number of plastic types used in packaging to the three main plastics used now: PET, PP and PE. Still, these three plastic types are not compatible and will also pollute each other in recyclates. This reaction to limit the number of plastic types also results in an increased opposition towards 'new' bio-based polymers in packaging applications. Limiting bio-based polymers to drop-in alternatives like bioPET, but in particular bioPE and bioPP, is not resource efficient. PLA, PBS and PEF would provide more resource efficient options. Moreover, the recycling potential of polyolefins like bioPE and bioPP seems markedly less positive than the recycling potential of bioPET [68,69], and in the development of a circular economy this should be taken into account. Polyolefins (PE and PP) take up fatty compounds during use, which reduce recyclate quality. This is not or far less the case for PET, and also for PLA and PEF this may be expected. Another advantage of PLA, PEF and PET is that their molecular weight can be repaired by an solid state post condensation (SSPC) treatment while at the same time volatile compounds are removed. In this way, food grade polymers can be obtained. Moreover, polyesters like PET, PLA and PEF, but also PA, can be chemically recycled more easily than polyolefins. Research should focus on bio-based polymers that fit within multiple EOL scenario's and cause less harm when littered. Questions to be answered are, a.o.: How would bio-based plastics fit best in a circular economy? Which materials meet the performance of currently used polymers: PE, PP, PET, etc.? Which are most circular and sustainable? How to get sufficient volume? How to get there?

3.4.4.7 Base targets for reuse, recycling, digestion and composting on overall life-cycle impact analysis

Directive 2018/852 and Commission Implementing Decision 2019/665 prescribe what may be counted as mechanical recycling: the weight of packaging which is actually reprocessed into products, materials or substances. This provides a solid base for where and how to measure 'recycling'. However, the overall goal is to achieve more than recycling alone: efficient use of resources, reduction of GHG emissions, reduction of other important environmental impacts. And mechanical recycling is not automatically the optimal way to achieve these goals (also see § 3.4.4.2).

When setting targets for mechanical plastic recycling without linking to life-cycle performance concerning different EOL options, pressure may increase to valorise lower value recycle fractions into products which need a lot more of material to meet product performance requirements than would be needed with virgin plastic, while the lower value recycle fraction could be well digested into valuable biogas. However, Directive 2018/851[70]. and Directive 2018/852[47] count waste that enters aerobic (composting) or anaerobic (digestion into biogas) treatment only as recycling, provided that such treatment generates output such as compost and digestate which is to be used as a recycled product or material, while conversion into fuels or other means to generate energy is not counted as recycling. As composting and anaerobic digestion of bio-based plastics virtually leaves no compost nor digestate, composting and digestion of bio-based products would not be considered as recycling. And even if digestion into biogas would leave some digestate, it yields 'fuel or other means to generate energy', so again it is not considered recycling. It is proposed that recycling includes both mechanical and chemical recycling, as well as composting and digestion. In addition it is proposed that choices for EOL routes are based on their environmental impact, and that targets take into account the overall life-cycle impact.

Regarding reuse, it needs to be clear how often a reusable packaging needs to be reused before it is better than a one way packaging from an overall impact point of view.

Targets for reuse and recycling need to be matched with reduction of overall life-cycle impact of products, so including material production (resource use efficiency) and the use phase of the packaging product: packaging serves key functions like protecting the product packed in it to retain its quality and to avoid its loss. Ultimately, targets need to be adapted to life-cycle impact steered design for recycling.

An independent authority (see §3.4.4.10) would be able to make recommendations to the EC for setting targets.

3.4.4.8 Design standards that regulate recyclates

Directive 2018/852 and Commission Implementing Decision 2019/665 already prescribe what may be counted as mechanical recycling: the weight of packaging which is actually reprocessed into products, materials or substances. However, almost 60 percent of the European plastics converting companies find it hard or very hard to get a supply of recycled plastics materials that meet their quality standards, reported the European Plastics Converters Association[56]. Development of EU wide quality standards for pre-sorted and sorted plastic waste, harmonisation of test methods for recycled plastic materials and certification of plastic recycling operations would help improve the quality and economics of plastics recycling.

Although such standards are not specifically relating to recycling of bio-based plastics alone, these measures are a pre-condition for bio-based recyclates to take off: quality should be clear and constant and supply secured; recyclates need to become a kind of commodity.

A standard on regranulate quality should focus on: 1) purity at flake level prior to re-granulation, not of blended granules, 2) performance of products made out of the regranulate, 3) traceability of the material (certification of origin) through a transparent system. The measuring point should be as close as possible to actual regranulation as a last step prior to actually manufacturing a new product, and the measuring point should be the same for volume and quality level. Calculation methods should be avoided as much as possible in order to limit space for stakeholders to find ways around the original idea and definitions.

It may be noted that as a rule of thumb quality requirements decrease when going from thin to thick products, and that processing becomes easier. Going from film to bottle to tray to injection moulding, generally product thickness increases, required material quality decreases and processing becomes easier[50].

Whereas responsibility for recycling of post-consumer plastic packaging lies with the producer, the producer is not responsible for EOL of post-industrial plastic waste, and industry may choose themselves how they dispose of plastic waste. Often the cheapest option is incineration. On the other hand, industrial waste has high purity compared to post-consumer waste after sorting. An example is cutting waste from thermoforming processes.

3.4.4.9 Establish an independent organisation responsible for clear balanced life-cycle impact data for products, including for EOL options

At present, LCA is performed according to a limited number of methodologies. However, for sake of keeping product manufacturing processes confidential, LCA studies often do not show the underlying data and assumptions in full. As a consequence, sometimes contradictory results of different LCA studies are published. The fact that LCA studies are performed by a multitude of universities, institutes and organisations does not help to end up with comparable and coherent LCA data.

All parties aiming at reducing the environmental impact of their activities benefit from clear LCA data for EOL options and actually the entire life-cycle for (groups of) products (also see § 3.2 on 'Sustainability certification for all products' in STAR4BBI project report D3.3 [71]). The entire cycle of a product would involve:

- material production: involving resource use efficiency and overall impacts for human health, climate change and ecological environment aspects
- product design: featuring functionality and EOL options
- use phase: taking into account product protection, including food safety (= human health), and reducing product loss
- EOL treatment: reuse, mechanical or chemical recycling, digestion into biogas, composting, incineration with energy (power) recovery
- effects of unintended littering should be included in life-cycle impact analysis; although traditional LCA methodologies cannot handle occasional events like littering[72], an independent organisation may establish balanced estimates based on actual littering data and their observed and reasonably expected effects
- consumer behaviour should be included in some way

Most common LCAs are performed to compare the impact of the manufacturing or EOL of just a few materials and/or products. Such LCAs are in depth studies based on as much as possible specific operational (factory) data. An overall life-cycle analysis as meant in this proposal involves generation of more generic data and the modelling of the impact of a wide variety of material-product-use-EOL chains to allow comparison of overall impact.

In the EU Strategy for Plastics in the Circular Economy[52] the Commission states it will identify with LCA applications where the use of biodegradable or compostable plastics have clear environmental benefits. In this context, the Joint Research Centre (JRC) was entrusted by the Directorate-General for Internal market, Industry, Entrepreneurship and SMEs (DG GROW) with the project "Environmental sustainability assessment comparing through the means of lifecycle assessment the potential environmental impacts of the use of alternative feedstocks (biomass, recycled plastics, CO_2) for plastic articles in comparison to using current feedstocks (oil and gas)". JRC is in the process of this study and is developing a harmonized LCA methodology to evaluate the potential environmental impacts of 1) the use of alternative feedstocks for plastic articles production in comparison to using current fossil-based feedstocks, 2) for making 10 different articles (beverage bottles, food trays, flexible food packaging films, wipes, chairs, automotive interior panel, mulch films, pots, insulation boards and printer housing panel), 3) and different potentially interesting EOL options. Currently this study has several shortcomings as highlighted in section 3.3.1. More specifically concerning the still low maturity-level of bio-based products, and allowing fossil-based products to use industry average data while bio-based products have to use individual company data. Furthermore using an average EOL scenario instead of taking the best EOL option for that product to make comparison which should be recommended as the intended EOL option.

It is proposed to establish an independent organisation responsible for performing LCA or collecting scientific impact data on bio-based materials and products for the several stages of product lives. The harmonized LCA methodology used by JRC could be used. For every different material in the market with a different raw material use and processing, an LCA would need to be performed. Then a market average could be made to make comparison on product category level. The full life-cycle of individual products would need to be considered and all relevant EOL options need to be analysed. As stated above when making comparison with the fossil reference for that product category, the potentially relevant EOL options should be taken. This is because recycling could be the best option in environmental terms for the fossil based product, this may not be automatically the best choice for bio-based, and in particular biodegradable, products. The organisation should interpret the results and make consultations with relevant stakeholders along the life cycle: material producers, product manufacturers, retailers, waste processors (sorters, recyclers, composters), municipalities, etc. On basis of that, comparable and balanced impact data for relevant impact categories should be established, including those for the several different packaging materials currently in use (glass, metals, paper, drinking cartons and plastic). The relevant impact categories as well as their actual relevance would need to be determined by politics.

Such impact data would allow a centralized advising authority (see §3.4.4.10.) to decide which is the best EOL option for (groups of) products, and to provide clear advise to governments, municipalities, consumers and waste processors. Additionally, it allows product manufacturers to include EOL in their product development based on data, and not on general features like e.g. compostability or recyclability.

3.4.4.10 Centralize the advising authority for EOL in one organisation

As a result of the emerging importance of recycling, even in a small country like the Netherlands, 3 different organisations provide recommendations for disposal of e.g. compostable plastics by consumers[3]. Consequently, recommendations are not uniform and confusing. The result is that municipalities, which are responsible for waste collection and processing have different policies regarding disposal of e.g. compostable plastics.

A centralized authority could result in uniform advises and guidelines for EOL routes for products, bundling of knowledge and know how, learning from best practices, etc. Such an authority would need to be independent. At the same time, it would need to closely collaborate with the wide range of stakeholders, including: Governments (EC, National ministries of environmental affairs and of economic affairs), municipalities, industry (not only packaging industry, but also product manufacturing industry), retail, waste processors and their customers (e.g. plastics processing industry for recyclate granules, farmers for compost), independent scientists, and also consumers. The authority would be responsible for drafting criteria and certification systems for packaging products (materials, recycled content, disassembly, EOL), sorting (post-consumer and post-industrial), recycling (mechanical and chemical, purity and quality), and organic waste conversion (composting, biological drying, anaerobic digestion).

This allows governments and municipalities to issue clear and consistent instructions for product manufacturers, waste processors and consumers. This may ultimately lead to a recycling scheme, which is clear to consumers, facilitates them for the optimal disposal of different types of products and which takes into account the way motivated and less motivated consumers act when disposing their waste products. Also, the scheme should not put any kind of pressure on consumers to dispose a product in a different bin than preferred based on LCA of the entire value chain and life cycle. Different habits and infrastructure in different countries and regions should not be a bottleneck to implement changes, but rather need to be considered and addressed.

With all the information and insights that the authority is going to collect, it may develop a roadmap for how to completely decouple from fossil-based to bio-based and propose measures to stimulate the transition towards circular materials and products.

The authority may also be responsible for introducing clear icons/labels indicating the preferable EOL route. The best EOL route for a product must be very clear to the consumer. And in particular cases it may be useful to indicate what is not the desired EOL route, e.g. for products which look like a particular material but in fact are not. The icon should be clear and large enough that they can be easily found and read/understood by consumers aged 10 – 100. Nowadays, icons are often very small, not readable nor clear to elderly people, and easily overlooked by young people.

3.4.5 Stakeholder consultation

During the workshop in Cologne in May 2019, 12 persons from various stakeholders like plastics producers, products manufacturers, knowledge institutes and a policy maker at a national government joined a discussion on EOL. The attendants basically agreed to the proposals to: 1) design for reuse and recycling, 2) establish an independent organisation responsible for balanced impact data for the entire life-cycle of (groups of) products and 3) establish a centralised authority for EOL.

They had following additional detailed points of view:

- LCA at product group level could work if products are produced in a similar way.
- There is already an authority office on industrial pollution which works well; it makes recommendations and follow ups, and industrial pollution levels have been reduced.
- Concern is that policy makers may not like to interfere; there needs to be an urgency/need for them to act accordingly. However, EOL is not a business case, so Governments need to interfere.

4 Conclusion and next steps

Some current regulations are found not to be aligned with innovations in the field of bioeconomy, and this is hampering the transition towards a sustainable European bioeconomy. This report proposes specific measures for updating regulations that are most in need of revision or demonstrate feasibility of successful adaptation with the ultimate objective of accelerating the transition to a bioeconomy.

Firstly, it is suggested to **tax the fossil carbon in fossil resources** at the point of extraction (when produced in the EU) or at EU Customs when they are imported by measuring the fossil carbon content of these resources. For products produced in the EU, the energy and fossil resources used as a feedstock or energy will automatically be taxed. For imported products, the fossil carbon in the products will be taxed. The energy used for producing the product should be taxed according to the energy tax of the importing country. The implementation of fossil carbon tax has a number of advantages: (a) it will allow the application of the tax at EU level, which will allow quicker agreement than if global agreement was necessary; (b) it will allow a carbon border adjustment by taxing imported products and reimbursing the tax to exporters; and (c) the mechanism will allow WTO rules to be respected, which is a significant hurdle for the integration of such taxing systems. The taxation rate has to be high enough to have an effect on the current market. We suggest that EU starts from the current EU ETS price (as a base for calculating the taxation rate for the fossil carbon tax) which should be set as the minimum price and should increase over time.

With regard to the **Compostability Standard**, the conclusion from research and interviews is that changing the standard (EN 13432) is not the solution for the current challenges in the market situation. The opposition of composters to biodegradable products does not depend on the standard as much as the fact that they do not accept any compostable plastic products. However, the Standard, which was developed in 2000, should be in line with current practice. As composting processes have changed considerably since then, a revision of the Standard is recommended. The goal is to come to an agreement that matches the industrial practices of today and the near future with what can be achieved for compostable plastics and for products for which composting may have benefits.

In addition, it is proposed to introduce a policy framework dedicated to bio-based materials called the **Renewable Materials Directive** similar to what currently exists for biofuels and bioenergy (RED) with the goal of creating a level playing field for bio-based products. This is predicted to be highly influential in accelerating the transition from fossil-based materials to bio-based alternatives, which has been considerably slow without the presence of supportive legislative mechanisms. It is proposed that policy support for bio-based products be awarded based on the solutions that they provide to current environmental and societal challenges. Specific mandates and bans should be considered accordingly for specific product groups that pose significant littering problems, including those with a high risk of unintended disposal in nature or high difficulty in collecting from the environment (such as mandatory use of biodegradable materials used in horticultural applications, hygiene articles, fishing nets, body bags). Furthermore, requiring materials used with food applications to be compostable/digestable should be considered to allow the diversion of food waste from landfills or incineration to where it can be composted or digested into biogas. If these materials are made compulsory to be compostable/digestable, consumers will not need to check for this characteristic. The main goal of the Renewable Materials Directive is to accelerate the shift from using virgin fossil resources for products to renewable carbon sources. Therefore, it is proposed to set a binding overall EU target for the share of renewable carbon in the industrial production of all products. Renewable carbon is considered to include, besides biomass, renewable carbon from recycling and from direct CO_2 utilization; all three are alternatives to using virgin fossil resources for carbon. Moreover, sector-specific targets for the specific sectors, such as chemicals and plastics sector, should be considered.

Plastic packaging is of great value to protect (food) products, prolong shelf life and reduce product loss. The production of sustainable and circular plastic packaging requires the use of bio-based and other renewable feedstock to compensate for inevitable loss of material, and plastic production should be decoupled from finite and GHG emitting fossil resources. The selection of the most preferred **end-of-life (EOL) route for bio-based plastics is a multi-component issue which needs to be addressed in coherence**. Packaging product design should keep reuse and recycling possibilities in mind. But ultimately, 'design for recycling' involves the entire life-cycle of products. The impact of material production relates to the resource use efficiency of converting feedstock into different bio-based plastics. Material selection and packaging product design affect functionality and EOL options of the plastic products. Reuse and mechanical recycling of plastics are nice EOL options, but in several cases composting or digestion of plastics may exhibit lower overall impact. It is proposed that Directive 2018/851 and 2018/852 be modified to include the value of digestion and composting of biodegradable plastics in the recycling targets, regardless of whether these processes deliver compost or digestate. The benefits/costs of the different EOL options should be based on impact analysis of the entire life-cycle, including as far as possible effects of littering and taking into account consumer behaviour. If mechanical recycling is the preferred option, regranulate quality should be important next to quantitative targets and standards for regranulate quality should be designed. An independent organisation would need to be responsible for balanced life-cycle impact data on bio-based materials and products, and as far as fossil-based or other products are being used, these should be included as well. The bioeconomy is still far away, and getting there requires a transition towards the use of bio-based feedstock in a circular economy and needs stimulating research. A centralized advising authority should provide uniform advises and guidelines for EOL routes for products, bundling of knowledge and know how, learning from best practices, etc. In connection the authority should provide criteria and certification systems for different stages along the life-cycle of packaging products. Such an authority would need to be independent, and at the same time it would need to closely collaborate with the wide range of stakeholders, including: Governments, municipalities, industry, retail, waste processors and their customers, independent scientists, and also consumers. With all the information and insights that the authority is going to collect, it may develop a roadmap for how to completely decouple from fossil-based to bio-based and propose measures to stimulate the transition towards circular materials and products.

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Appendix A. EU policies related to bio-based products

The policies related to bio-based products include the following:

The **Bioeconomy Strategy** (update, 2018[38]) and action plan aims at mobilisation of public and private stakeholders to foster research and innovation investments for the development of substitutes to fossil based materials with bio-based resources. Also to accelerate the deployment of sustainable and circular bio-based solutions.

The renewed **Industrial Policy** (2017)[36] sees development of the bio-economy as a key to accelerate progress towards a circular and low carbon economy. It is presented as one of the priority areas with a high potential for future growth.

The **Circular Economy** Package and Action Plan[39] aims at creating a circular, resource-efficient economy through greater recycling and re-use. It is written that the biological resources should also be used in a circular way. It is written that "The bioeconomy hence provides alternatives to fossil-based products and energy, and can contribute to the circular economy. Bio-based materials can also present advantages linked to their renewability, biodegradability or compostability." Only action stated in this regard is for R&D.

The **Plastics Strategy**[52] states that the Commission will assess the lifecycle impacts of alternative feedstock used in plastics production, including biomass. Based on the results, the Commission will support the development of alternative feedstocks in plastic production. It is written that according to solid evidence that they are more sustainable, the uptake of bio-based product will decrease our dependency on fossil fuels. It is also added that the Commission will identify with life cycle analysis, applications where the use of biodegradable or compostable plastics have clear environmental benefits. It is acknowledged that biodegradable plastics can certainly have a role in some applications.

The EU **Waste legislation on packaging and packaging waste** (2018)[47] includes counting of organic recycling of biodegradable packaging waste towards recycling targets. It is stated that "Bio-based recyclable packaging and compostable biodegradable packaging could represent an opportunity to promote renewable sources for the production of packaging, where shown to be beneficial from a lifecycle perspective." It is further written down that single use packaging may be indispensable to guarantee food hygiene and the health and safety of consumers in some applications. For these cases Member States should take measures to ensure recycling of such packaging. One of the fears concerning this directive is that the quality of the recycled plastic and its applications are not considered in setting up the recycling targets (see §3.4 for further discussion).

The **Waste Framework** Directive[70] aims at reducing environmental and health impacts of waste generation and management, as well as, at encouraging resource efficiency through reuse, recycling and recovery through introduction of a waste hierarchy. It also presents the end-of-waste criteria which specifies when certain waste ceases to be waste and obtains a status of a product or a secondary raw material. There are specific concerns of the applicability and restrictions of the waste framework directive for bio-based products with biodegradation or composting being not covered and lack of clear definition of waste hampering its use for bio-based products (see STAR4BBI D3.3 suggestions for improvement of the Waste Framework Directive).

EU Directive on **Single-use Plastics**[42] proposed a comprehensive set of measures, to help tackle plastics waste. The Directive includes a ban on plastic items such as straws, plates, cutlery, coffee stirrers and plastic balloon holders. In addition European Parliament proposed that Member States will have to cut their use of food containers and cups for beverages. The single-use plastics directive therefore fails to acknowledge the potential of biodegradable and compostable plastics (see §3.3 where it is proposed to include mandatory use of compostable plastics for single-use plastics where they are required to provide food safety and hygiene).

EU **RED** (renewable energy directive)[35] promotes the production of energy from renewable sources. The Directive sets out sustainability criteria to ensure that they are produced in a sustainable and environmentally friendly manner. No such supportive legislative mechanism exists for the use of renewable sources for materials furthermore RED puts pressure on availability and price of biomass for materials resulting in market distortions (see §to provide balanced support for energy and material use of biomass).

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