Biobased Feedstock for Plastics

Sustainability criteria and policy measures for production of plastics from sustainable biomass feedstock

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Contents

SUMMARY		**4**
1.	**INTRODUCTION**	**6**
1.1	**Background**	**6**
1.2	**Scope of the assignment**	**7**
1.3	**Approach and structure of the report**	**8**
2.	**PLASTICS IN SWEDEN**	**9**
2.1	**Production and consumption of plastics in Sweden**	**9**
2.2	**Production pathways for biobased plastics**	**13**
3.	**BIOMASS FEEDSTOCK FOR PRODUCTION OF PLASTICS**	**17**
3.1	**Types of biobased feedstock**	**17**
3.2	**Feedstock potentials**	**17**
3.3	**Suitability of feedstocks for plastic production**	**20**
4.	**CURRENT RELATED EU POLICIES**	**24**
4.1	**The Packaging and Packaging Waste Regulation**	**26**
4.2	**Ecodesign for Sustainable Products**	**27**
4.3	**The Sustainable Taxonomy**	**29**
5.	**POSITIONS FROM STAKEHOLDERS**	**31**
5.1	**Published positions**	**31**
5.2	**Input from stakeholder contacts and interviews**	**33**
6.	**CURRENT USE OF SUSTAINABILITY CRITERIA FOR BIOMASS FEEDSTOCK**	**37**
6.1	**Principles for and use of sustainability criteria**	**37**
6.2	**Sustainability and GHG criteria in RED III**	**39**
6.2.1	Legal structure and applicability	39
6.2.2	Land use related criteria	41
6.2.3	Greenhouse gas emissions savings criteria	42
6.3	**Sustainability criteria in voluntary schemes and standards**	**44**
6.3.1	Voluntary schemes approved under the RED	44
6.3.2	Voluntary schemes for certification of feedstock	45
6.3.3	Standards	46
6.3.4	Product environmental labelling	48
7.	**SUSTAINABILITY CRITERIA FOR BIOBASED PLASTICS**	**52**
7.1	**Principle considerations and summary of analysis**	**52**
7.2	**Land use related criteria**	**55**
7.3	**Criteria for GHG emission savings**	**55**

7.3.1	Fossil comparators and required savings	55
7.3.2	REDIII GHG Calculation methodology applied to biobased plastics	57
7.3.3	GHG emission calculation in standards for LCA	60
7.3.4	Other relevant GHG emission calculation methodologies	61
7.3.5	Chain of custody in LCA	63
7.4	**Implementation of sustainability criteria for biobased plastics**	**64**
7.4.1	Summary and discussion on technical aspects of implementation	64
7.4.2	Options for regulatory implementation	68
8.	**NATIONAL POLICY MEASURES TO ADVANCE BIOBASED PLASTICS**	**72**
8.1	**Green Public Procurement**	**73**
8.1.1	General background on GPP	73
8.1.2	Examples of Green Public Procurement for biobased plastics	74
8.2	**Blending obligations**	**75**
8.2.1	General background on blending obligations	75
8.2.2	Example of blending or quota obligations	76
8.3	**Reduction of taxes**	**77**
8.3.1	Examples of taxes on plastics	77
8.4	**Fees**	**78**
8.5	**Operational aid through contracts for difference**	**79**
8.5.1	UK CfDs for energy	80
8.5.2	Financial CfDs (for energy)	82
8.5.3	Considerations for bioplastic-CfDs	83
8.6	**Summary of feasibility and implications of alternative policies**	**85**
9.	**CONCLUSIONS**	**90**
APPENDIX 1. INTERVIEWEES		**93**
APPENDIX 2. MATERIAL FLOWS FOR THE STENUNGSUND CLUSTER		**94**
APPENDIX 3. FEEDSTOCK TO REFINERY		**95**
APPENDIX 4. GHG EMISSION CALCULATION EXAMPLE		**96**
APPENDIX 5. PEF AND P-LCA METHODS		**97**

Summary

The Swedish Environmental Protection Agency (Swedish EPA) has been commissioned to drive the phasing out of fossil virgin raw materials for plastic. One of the potential alternatives is to switch to more bio-based raw materials. To complement the knowledge base for this work, the Swedish EPA has assigned CIT Renergy to investigate measures required to increase the production of biobased plastics (BBP). The assignment partly included investigating how sustainability criteria for biomass used as feedstock for plastic production could be designed, partly to investigate potential national policy measures to foster the advancement of biobased plastic production. This report includes the result of this assignment.

As background to the two main areas in focus, an overview of the production and consumption of plastics in Sweden, production pathways for BBP and potential biomass feedstocks for plastics is provided. Further, positions from stakeholders have been summarized based on both literature and on interviews carried out within the project.

In Sweden, in 2023, about 1 million tons of plastic material was produced, and about the same volume of plastic material was put on the Swedish market. However, a major share of the domestically produced volumes is exported, and other plastic material is imported.

The share of biobased plastics is in general very small – in the EU it is less than one percent of all plastic produced. In Sweden, there are some examples, where small shares of biobased feedstock have been introduced in the production of PVC, ethylene and propylene. Overall, the production pathways for BBP can be classified as either drop-in or substitution plastic. This classification has implications for the implementation of sustainability criteria.

In the report, the investigation of sustainability criteria for BPP includes a detailed description of the current use and implementation of sustainability criteria in the current version of the Renewable Energy Directive (RED III), voluntary schemes and in LCA frameworks. Based on this, implications and potential strategies for implementation of criteria for BBP are discussed. The conclusion is that land use related sustainability criteria for BPP can and should be directly based on the criteria used in the RED III.

Potential implementation of GHG emission criteria is more challenging and cannot be directly transferred from RED III to BBP. The methodology in RED III needs to be adapted. In this adaptation choices need to be made related to product granularity and value chain position for which to apply

the criteria, product specific fossil comparators, required savings relative to these comparators, principles for allocation of emissions in co-processing and handling of end-of-life emissions. Substantial development work is needed to develop methodology and GHG emission values for fossil comparators and default BBP value chains (both for drop-in and substitution value chains).

To enable the industry to develop stepwise towards more biobased raw material, the chain of custody principle used should allow for co-processing of fossil and biobased feedstock and a certain level of mass balancing when allocating emissions to different products. The LCA frameworks (including PEF) do currently not include such methods, which limit the possibilities to base the implementation directly on these frameworks. Therefore, the most feasible approach would be to align as closely as possible to the provisions and principles used by the RED III. Simplified approaches to implementing national sustainability criteria could be to apply RED III land use related criteria only or directly refer to criteria in existing certification systems.

The investigation of potential national policy measures to foster the advancement of BBP production includes an overview of measures that have been proposed in literature or implemented in other countries and/or policy areas. The overview includes green public procurement, blending obligations, reduction of taxes or fees imposed on plastic production and/or use, and contracts for difference. In summary, it is concluded that binding national BBP policy measures in one of the EU member states is associated with a risk of interfering with parallel EU regulations (existing and awaited) affecting the markets. The system boundaries set for the regulated system imply a risk of creating unwanted and/or unexpected market effects. With this said, within the EU, national measures relating to plastics production – primarily based on recycled feedstocks - are applied.

Further development and increased production of BBP has the potential to contribute to decreased dependence on fossil resources and reduced climate impact from plastic value chains. It is possible to move forward at the national level, but the implementation of complete sustainability criteria at EU level and binding policy measures comes with significant methodological and regulatory complexities and the development will require substantial resources. A potential strategy could therefore be to, in anticipation of EU wide developments, implement a simplified approach for sustainability criteria, for instance based on land use related criteria only, and initially link them to implementation of green public procurement, voluntary labelling systems etc. Policy and criteria could then be gradually strengthened in tandem, ideally, in alignment with EU as a whole and with ongoing methodological development.

1. Introduction

1.1 Background

In Sweden, waste is largely incinerated in waste incineration plants to be converted into district heating and electricity (i.e. energy recovery). To achieve climate goals and sustainable plastic use, the amount of fossil plastic that is incinerated needs to be reduced.

The Swedish Environmental Protection Agency (Swedish EPA) is tasked with driving the phasing out of fossil virgin raw materials for plastic. One of the alternatives is to switch to more bio-based raw materials. This would, for example, reduce climate impact from greenhouse gas emissions from the combustion of plastic. In previous government assignments[1], the Swedish Environmental Protection Agency has stated that in such a transition it is vital that the bio-based raw material is produced sustainably. Sustainability criteria for bio-based raw materials currently exist for biofuels through the Renewable Energy Directive (RED), but no corresponding criteria exist when the raw material is used for polymers and plastics. However, while the criteria in RED might be relevant for all product categories they are currently not adapted to other uses of the raw bio-based material. Any possible adjustment of RED for this purpose must be analysed in more detail. Other relevant EU legislation will also need to be analysed. Furthermore, possible and effective instruments for a transition to more bio-based raw material will also need to be analysed.

The same issues are in focus at the EU level. In 2022, the Commission published a communication on policy framework on biobased, biodegradable and compostable plastics that underlined that the use of biomass, among other things, must be environmentally sustainable and should align with the circular economy principles. Currently, the European Commission is preparing for its obligations in 2028 established in the Plastic Packaging and Packaging Waste Regulation (PPWR). As stipulated in Article 8, the Commission has to review the technological development and environmental performance of biobased plastic packaging, taking into consideration the sustainability criteria laid down in e.g. RED. If the Commission finds it appropriate, it shall present a legislative proposal to lay down sustainability requirements for biobased feedstock in plastic

[1] Naturvårdsverket (2024). *Rätt plast på rätt plats.* Slutredovisning av regeringsuppdrag, ärendenummer NV-09904-21. 2024-03-14. https://www.naturvardsverket.se/494311/globalassets/amnen/plast/hallbar-plastanvandning/ratt-plast-pa-ratt-plats-slutredovisning.pdf

packaging and targets to increase the use of biobased feedstock in plastic packaging.

Further, also in 2022, the European Commission published an extensive study, carried out by Trinomics, Wageningen University & Research and Wood[2], on biobased plastic sustainable sourcing and content. The objective was to support the Commission's work on a policy framework for biobased plastics (BBP) and, in particular, to identify policy options that could ensure the promotion of BBP on the EU market that result in environmental benefits.

1.2 Scope of the assignment

The Swedish EPA formerly investigated the possibilities for providing economic support for a transition from fossil virgin plastic production, primarily focusing on recycling of plastic[3], and the status of biobased feedstock for plastic production in Sweden[4]. This assignment has a strict focus on the measures required to increase the production of biobased plastic (BBP).

The assignment includes two separate parts:

1) To investigate how sustainability criteria for biomass used as feedstock for plastic production could be designed. Basing this on RED III and other relevant EU regulatory frameworks, and under the precondition that sustainability criteria for bioplastics should not be stricter or more encompassing than the existing RED III-criteria for biofuels.
2) To investigate suitable policy measures to foster the advancement of biobased plastic production.

Thus, the overall scope and purpose of this study is overlapping strongly with the EC study referenced above[2]. However, for this study, the main focus is on the plastic industry in Sweden and the possibilities to introduce national measures. Also, it is carried out three years later, during which the knowledge, literature and processes nationally and within the EU have

[2] European Commission: Directorate-General for Environment, Trinomics, Wageningen and Wood (2022). *Biobased plastic – Sustainable sourcing and content – Final report*, Publications Office of the European Union. https://data.europa.eu/doi/10.2779/668096

[3] Hammar et al (2021). *Ekonomiskt stöd för omställning genom utbyte av fossil jungfrulig plast*. Naturvårdsverket, rapport 6979. https://www.naturvardsverket.se/4ac636/globalassets/media/publikationer-pdf/6900/978-91-620-6979-7.pdf

[4] Brännström et al (2022). *Bioråvara till plast, nuläge och trender*. IVL Svenska Miljöinstitutet, rapport C 653. https://www.diva-portal.org/smash/get/diva2:1651150/FULLTEXT01.pdf

evolved further. The report is used as an important source, but the analysis here has been carried out independently of the findings presented there.

1.3 Approach and structure of the report

The study and analyses presented in this report is primarily based on available literature and data related to the status of plastic industry, sustainability criteria and the development of policy measures for fostering a transition to more sustainable production value chains.

In addition, interviews have been carried out with key representatives of the Swedish plastic industry; branch organizations for different steps in the value chain, including potential feedstock providers and bioplastics; and experts of the EU policy development within the area. The interviews contribute with input for both parts (sustainability criteria and potential policy measures). The interview responses are summarized in a separate section (see below) but has also influenced the overall analysis presented in other parts of the report. The organizations and persons that have been interviewed are listed in Appendix 1.

The report is structured in the following sections:

- As an extended background, Chapters 2, 3 and 4 include a compiled description of the current situation for the Swedish plastic industry, potential biomass feedstock for production of plastic, and a concise overview of current related EU policies.
- In Chapter 5 stakeholder input based on literature and interviews is summarized.
- Chapter 6 and 7 include a detailed description and analysis of the sustainability criteria for biobased feedstock. First, the current use of sustainability criteria for biofuels and in other schemes are described (Chapter 6). Second, the potential implications of implementing similar criteria for the production of BBP are analysed and discussed (Chapter 7).
- In Chapter 8, examples of national policy measures that could potentially be introduced (in combination with sustainability criteria) to advance BBP are presented and the implications of them summarized.
- Finally, Chapter 9 contains summarized conclusions and discussion.

2. Plastics in Sweden

2.1 Production and consumption of plastics in Sweden

In 2023 less than one percent of the plastic produced in the EU was biobased, equivalent to approximately 2.18 million tons. EU has set a target of reaching 20 percent biobased plastic by 2030 but the increase towards this goal is slow, despite major investments in production sites especially in Asia, as the overall production of plastics is also growing. The forecast for 2028 is an increase in global production of BBP to 7.4 million tons, whereof 4.6 million tons is biodegradable. This can be compared with a total global plastic production of 400.3 million tons in 2022[5], which, by 2030, is estimated to reach stunning 483 million tons[6]. Consequently, the BBP will still only constitute about one percent of the total annual production.

BBP is mainly used for packaging, which in 2023 accounted for 43 percent (934,000 tons) of the EU market. It is likely that this ratio is representative also for Sweden.

The Swedish EPA carried out an overview of the state of plastic usage in Sweden for the year 2023.[7] The overview showed that Sweden imported approximately 1,119,000 tons of plastic raw material in 2023. Exported and domestically produced plastic volumes were 1,088,000 and 1,046,000 tons respectively. This means that about 1,077,000 tons of plastic raw material were put on the Swedish market (see Figure 1). The gap between plastic raw materials on the Swedish market and plastic found in products is mainly due to imports of plastic-containing products and exports of domestically processed plastic raw material. These trade flows are complex and were not examined in detail in the Swedish EPA survey.

[5] Plastics Europe (2023). *Plastics - the fast Facts 2023.* https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2023/ (Accessed 2025-11-15)

[6] Statista (2025). *Production forecast of thermoplastics worldwide from 2025 to 2050.* https://www.statista.com/statistics/664906/plastics-production-volume-forecast-worldwide/ (Accessed 2025-11-30).

[7] Naturvårdsverket (2025). *Kartläggning av plastflöden i Sverige 2023.* Rapport 7191. https://www.naturvardsverket.se/49ed44/globalassets/media/publikationer-pdf/7100/978-91-620-7191-2a.pdf

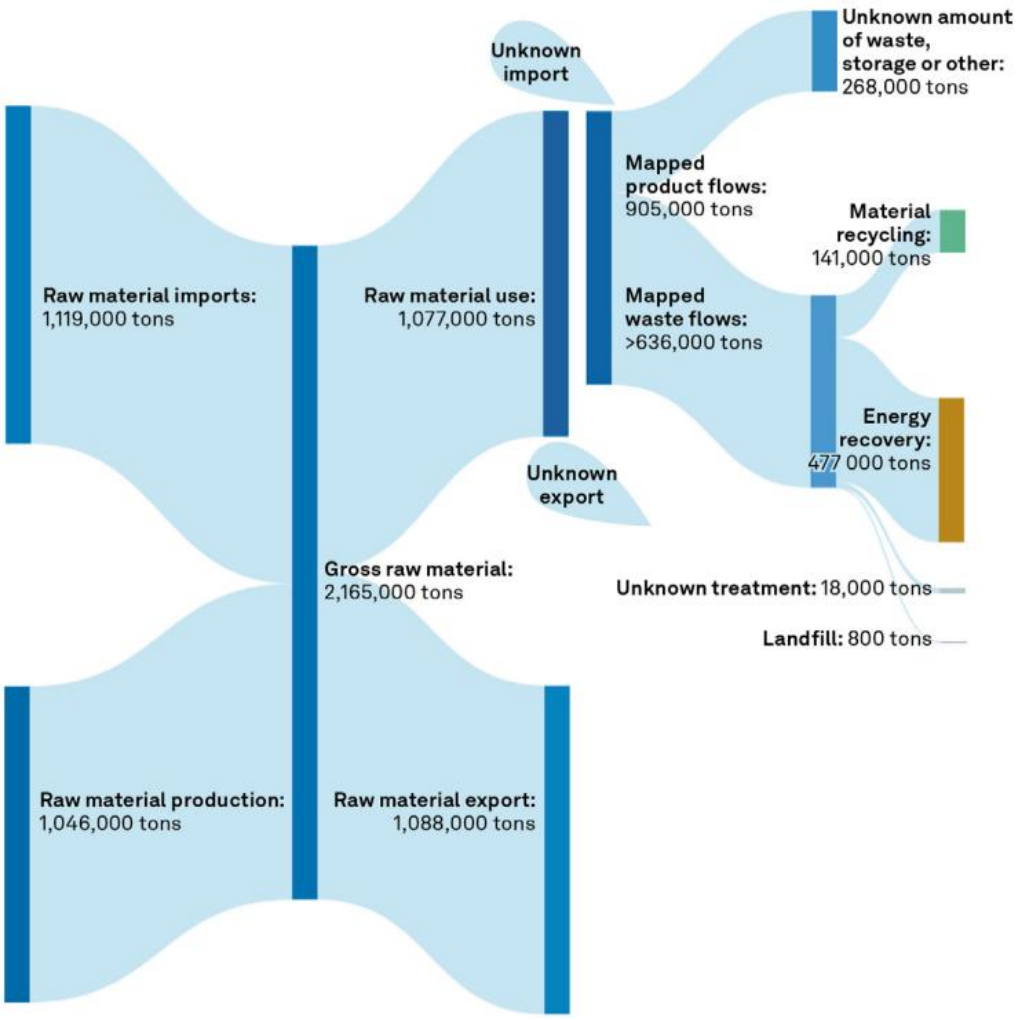

Figure 1. Overview of mapped plastic flows: raw material, plastic containing products and product related waste flows. Plastic in mixed waste flows are not included.[7]

Given the broad range of plastic applications, the mapping study chose to focus on key plastic flows involving large quantities in the overview of plastic usage in Sweden for the year 2023. The total plastic usage was at least 905 000 tons in the surveyed product groups, see Figure 1.

The largest use category was packaging (307,000 tons), followed by construction products (247,000 tons), vehicles (114,000 tons) and tires (54,000 tons). The plastic placed on the market (tons) and the plastic waste generated (tons) in 2023 for respective product category that were analysed are shown in Table 1.

Table 1. The plastic placed on the market (tons) and the plastic waste generated (tons) in 2023 for respective product category that were analysed in the report by the Swedish Environmental Protection Agency. DS=Data not available.[7]

	Plastic placed on the market 2023 [tons]	***Plastic waste generated 2023 [tons]***
Packaging incl. PET deposit bottles	307 000	307 000
Construction products *- of which indicator products*	~247 000[A] 26 000*	208 000
Vehicles	114 000	33 000
Tyres	54 000	37 000
Synthetic textiles: *- Clothing & home textiles* *- Geotextiles*	 47 000-81 000 16 000	 DS DS
Electrical equipment	41 000[B]	18 000
Agricultural plastic	19 000	15 000
Thermoset composite products: *- Wind turbine blades:* *- Leisure boats:*	 11 000 12 000	 < 2000 7 000-13 000
Toys and sports equipment	9 000	DS
Medical products within regional healthcare	>6 000*	>6 000
Furniture and home décor	>5 000*	DS
Fishing equipment	200	100
Artificial grass and activity surfaces	DS	DS
Total product flows	**905 000**	**636 000**

*Indicator products only.
A: Estimation based on data from Plastic Europe (2024).
B: Value for 2022.

In Sweden, the major producers of plastic raw materials are Borealis and Inovyn in Stenungsund, which produces polyethylene (PE) and polyvinyl chloride (PVC), respectively.[8] Borealis activities include a cracker and a polyethylene (PE) plant. The cracker thermally "cracks" feedstock like ethane, naphtha, propane and butane into unsaturated hydrocarbons. The main products are ethylene and propylene. In 2024, the production of

[8] Brännström et al (2022). *Bioråvara till plast, nuläge och trender*. IVL Svenska Miljöinstitutet, rapport C 653. https://www.diva-portal.org/smash/get/diva2:1651150/FULLTEXT01.pdf

ethylene was 594 ktons and the production of propylene was 169 ktons. Through a decision in 2024 from the County Administrative Board, the possibility of taking in bio-raw material through a 10 % mixture of biodiesel in the naphtha is allowed.[9]

Ethylene is used by Borealis and Inovyn in the production of PE and PVC respectively, but also by other industries in the symbiotic cluster in Stenungsund (see Figure 2).

In 2024, the production of polyethylene (PE) at Borealis was 523 ktons. The permit allows a production of 750 kton of PE.[10] The production of polyvinyl chloride (PVC) at Inovyn in 2024 was 215 kton. The permit allows a production of 260 kton. [11]

[9] Borealis (2025). *Borealis AB, Krackeranläggningen* (Miljörapport 2024). https://www.borealisgroup.com/storage/Milj%C3%B6rapport-2024.pdf

[10] Borealis (2025). *Borealis AB, Polyetenanläggningen* (Miljörapport 2024). https://www.borealisgroup.com/storage/Milj%C3%B6rapport-2024.pdf

[11] INOVYN Sverige AB (2025). *Miljörapport för 2024*.

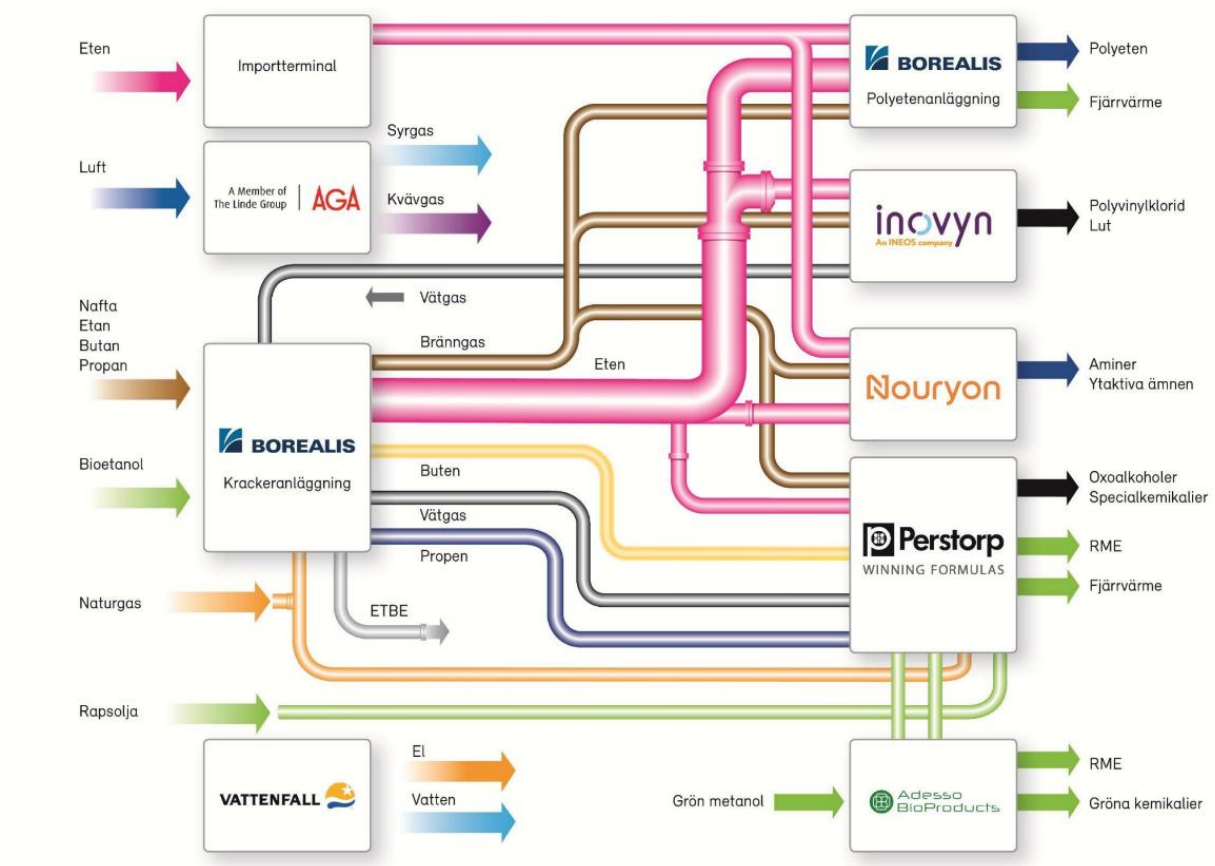

Figure 2. Material flows for the Stenungsund cluster. A larger picture can be found in Appendix 1).[12]

2.2 Production pathways for biobased plastics

The production of plastics from biobased raw materials can be classified into two main groups: drop-in or substitution plastic. The drop-in varieties have the same molecular structure and thus technical properties as their fossil counterparts. This means that they theoretically can be processed in the same way, have the same properties, and thus be used for similar products. They can also be recycled within the same system as their fossil

[12] Borealis (2022). *Ändringstillstånd Krackeranläggningen - Kemisk återvinning av plast* (Samrådsunderlag). https://www.borealisgroup.com/storage/220301-Borealis-samr%C3%A5dsunderlag-anl%C3%A4ggning-kemisk-%C3%A5tervinning_2022-03-29-091510_vplh.pdf

counterpart. Examples of drop-in plastics are biobased polyethylene (PE) and biobased polypropylene (PP). Worth mentioning are also biobased polyethylene terephthalate (PET) and some of the polyamides (PA) that are partially biobased. Recently biobased polyethylene furanoate (PEF) have been accepted to be recirculated in the same streams as PET

Substitution plastics on the other hand have different molecular structures than current fossil-based plastic.[8] Despite the differences in chemical structures, the properties of the materials might still enable them to replace current fossil-based alternatives. The most abundant biobased plastic polylactic acid, PLA, is an example of a substitution plastic commonly used for packages, disposable tableware, nonwoven fabrics, 3D printing etc. Other examples of substitution plastics are polytrimethylene terephthalate, PTT, often used in various textile applications, and polyhydroxyalkanoates, PHA, with applications within the medical industry as sutures, meniscus repair and others.

The most established route for commercial production of BBP is by utilising sugar cane, corn or other crops with easily accessible sugars or starch that can be modified to biobased ethanol, which is then converted to ethylene, the building block for polyethylene.

To avoid the debate of using sources that can be used for food or feed, but also to widen the possible sources the petrochemical industry has searched for other raw materials that can be used, such as forest raw materials, used cooking oil, fats, or vegetable oils as a source for production of biobased polymers. A general overview of the processes is shown in Figure 3.

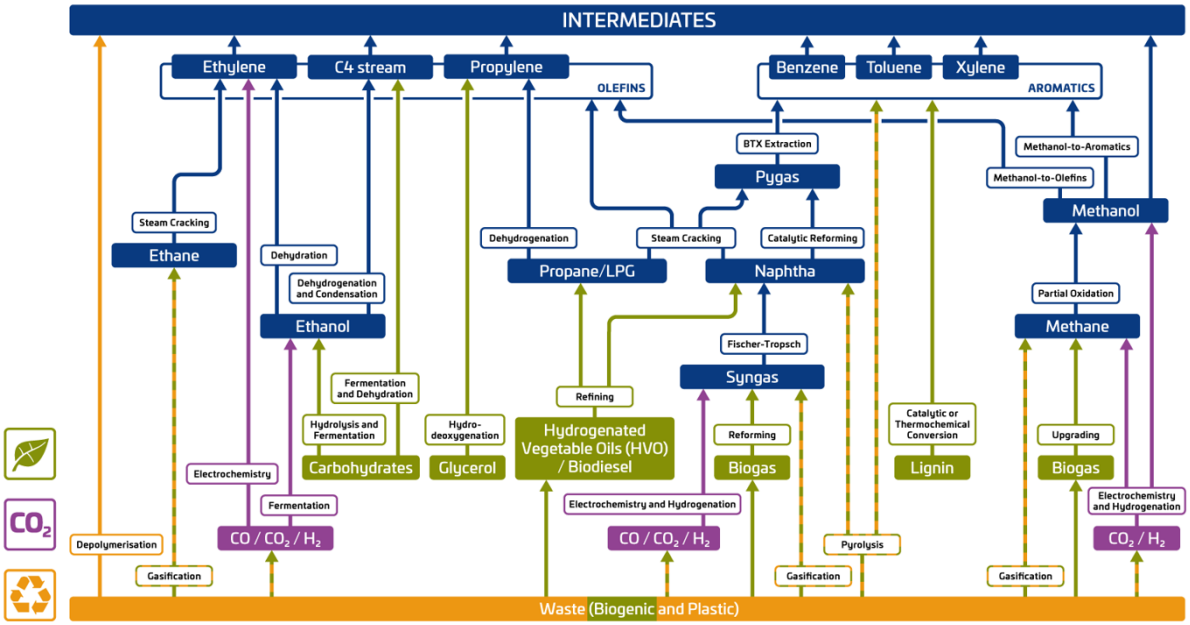

Figure 3 Biobased and/or recycled feedstock to refinery. A larger picture can be found in Appendix 2.[13]

Developments are ongoing within both academia and industry to identify new viable process routes going from different potential non-fossil based feedstock to the intermediates required as building blocks in most plastics.

A few examples where alternative resources have been introduced by utilisation of principles of massbalance are Borealis introduction of minor percentage of biobased feedstock in their cracker and Inovyns production of bioattributed PVC Biovyn.

In 2019, INEOS Inovyn was the first to produce a PVC where the fossil oil had been replaced with biomass from forest waste. From autumn 2024, used cooking oil is used as the raw material for BIOVYN produced in Stenungsund. In Sweden, BIOVYN is used in various fields of application, e.g. floors, carpets, rainwear, and the automotive industry.[11]

In the fall of 2021, Borealis conducted trials with a thousand tons of biobased raw material (crop by-product) in the existing cracker to produce biobased ethylene and propylene.[14] A generic overview of the process is found in Figure 4.

[13] Nova Institute (2025). *Renewable Carbon Refinery*. https://renewable-carbon.eu/publications/product/renewable-carbon-refinery-png/. (Accessed 2025-10-30)

[14] Borealis (2021). *Första testet med förnybar råvara i Borealis kracker i Stenungsund*. https://www.borealisgroup.com/storage/2021-sept_f%C3%B6rnybar-r%C3%A5vara-till-krackern-i-Stenungsund.pdf

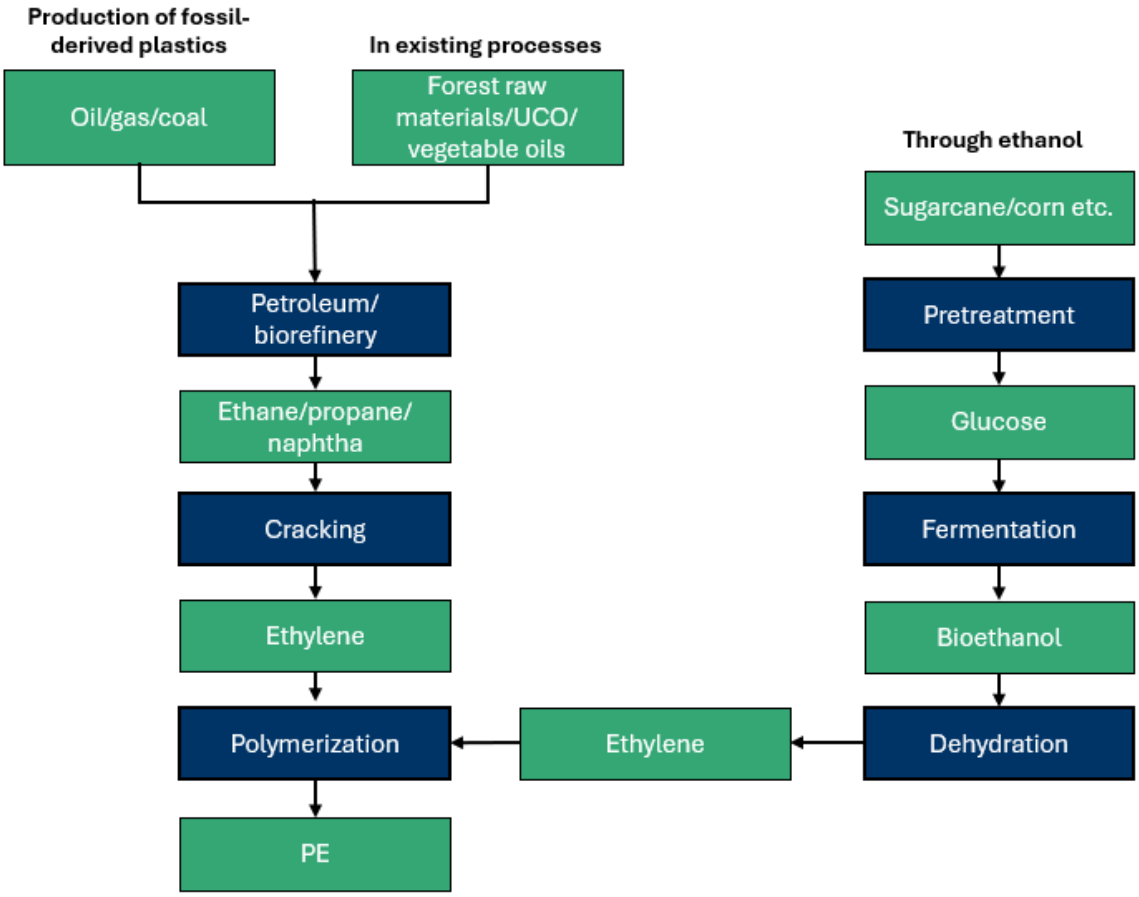

Figure 4 Overview of process routes for fossil (conventional) and biobased drop-in PE. Authors' translation of Swedish original in reference.[8]

For production of propylene there is currently a biorefinery step converting the biobased raw material from the forest industry, used cooking oils etc. into propylene. In parallel, pilot scale work is ongoing to produce propylene instead of the established route to ethylene. Propylene is then polymerized to polypropylene (PP).

It is also possible to convert methane to methanol and then to ethylene and propylene by the MTO (methanol-to-olefins) process. This can be used to produce the plastics polyethylene and polypropylene.[8]

3. Biomass feedstock for production of plastics

3.1 Types of biobased feedstock

The most important raw materials for bioplastics both in Sweden and globally are forest-based raw materials, agriculture-based raw materials, marine-based raw materials, and biogenic flow of waste.[15] Which feedstock that is used in respective country, is dependent on what is the most abundant crop and thus likely the most economical solution for each site, like sugar cane in Brazil, corn in North America, wheat and potatoes in Europe and forest products in the Nordic, to generalize.

Sugar cane is the most common source for the polyolefins due to the easily accessible sugars that can be fermented to alcohols and then to olefins. Corn, wheat and potatoes are rich in starch which also by fermentation can be used in production of olefins. Starch rich crops are also used for the production of polylactic acid, PLA, one of the more common biobased substitution plastics.

3.2 Feedstock potentials

As noted in Material Economics[16], the different aspects of the bioeconomy – food/feed, bioenergy and biomaterials – are seldom discussed together, which means that integrated projections for total future production and use are rare. Studies of the potentials for increased use of bioenergy do, however, in general exclude current use of biomass for production of materials and in some cases take projections for increasing use of biomaterials into account. Thus, they take as a starting point biomass feedstock for production of material is prioritized above use for bioenergy.

This is, for instance, the case in the estimates by DGRI (2024), which presents three different scenarios for the total EU biomass potential available for advanced biofuels, ranging from 115 Mtoe in the low scenario to about 350 Mtoe per year in 2050 in the high scenario (corresponding to

[15] Lagerstedt Eidrup, M.-L.; Lindgren, A.; Heyne, A. & Voogand, E. (2023). *Områdesanalys – Biobaserade plaster*. Stiftelsen Chalmers Industriteknik. Bio-innovation. https://wwwbioinnovation.cdn.triggerfish.cloud/uploads/2023/01/omradesanalys-biobaserad-plast.pdf

[16] Material Economics (2021). *EU Biomass Use in a Net-Zero Economy - A course correction for EU biomass*. https://materialeconomics.com/node/3. (Accessed 2025-09-01)

1300 – 4000 TWh), including current use. In comparison, the total potential for additional bioenergy use in Sweden has been estimated to between 33 and 54 TWh per year and current total use of bioenergy in Sweden is about 150 TWh. [17] In the sub-sections below, the estimates of the Swedish potentials for biobased feedstock from different types of biomass (based on studies primarily focusing on the potential for biomass use for energy), are summarized. The link to feedstock for biobased plastic are shortly discussed in Section 3.3.

FOREST-BASED RAW MATERIALS

The forest is a major source for biobased raw materials in Sweden. Examples of forest-based raw materials that can be used to produce bioplastics are sawdust, black liquor, lignin, tall oil etc.[18] Their composition (cellulose, lignin etc.) varies, therefore they are more or less suitable as raw materials for e.g. bioplastics; when used as raw material, they often need some kind of pretreatment. Currently, they are often used for energy purposes and quantified in energy content units. Based on long term predictions for felling and on scenarios for the Swedish forestry, accounting for different developments in policy, technology, market and climate, a recent study[19] estimates the bioenergy potential in unprocessed forest residues (including tops and branches, defective roundwood, but not stumps and roots)[20] to between around 14 TWh/year and 39 TWh/year between 2030 and 2050, depending on scenario. The same study estimates the potential in by-products from wood processing (sawdust, bark, lignin) to between 19 TWh/year and 43 TWh/year in 2030 and 2050, depending on scenario. In addition, the potential in biomass in low value trees from clearing power transmission right-of-ways, roadsides, railways, and field edges in 2030 and 2035 is about 3 and 10 TWh respectively. Fast growing

[17] European Commission, Directorate-General for Research and Innovation, BEST, BTG, E3Modelling, Exergia, POLITO, Wageningen University & Research, (2024) *Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels: final report* and *Annex 2*. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/679307. See also f3 Fakta (2025). *Potential för användning av biomassa för energi inom EU – En sammanställning från fyra studier* (in Swedish). f3 Innovation Cluster for Renewable Transport Fuels. https://f3centre.se/app/uploads/f3_faktablad-7-2025_FINAL.pdf

[18] Brännström et al (2022). *Bioråvara till plast, nuläge och trender*. IVL Svenska Miljöinstitutet, rapport C 653. https://www.diva-portal.org/smash/get/diva2:1651150/FULLTEXT01.pdf

[19] Börjesson, P. (2025). *Förändringar i tillförselpotential av långsiktigt hållbar skogsbiomassa.* (IMES/EESS Rapport; Nr 140). Miljö- och energisystem, LTH, Lunds universitet. https://lucris.lub.lu.se/ws/portalfiles/portal/218093319/Tillfo_rselpotential_av_skogsbiomassa_-_Rapport_Nr_140_2025_.pdf

[20] The latest revision of the Renewable Energy Directive from November 2023 stipulates that harvesting of stumps and roots must be avoided to maintain biodiversity and for soil reinforcement. Therefore, this amount has been left out.

spruce on fallow land is estimated to between 0,5 and 1 TWh in 2045 and 2050 respectively.

Tall oil is a byproduct from pulp and paper industry that is currently used as raw material for HVO or chemical components. Other byproducts are mainly used for energy purposes, either internally or externally. A study from 2018[21] presents today's production of products from forest industries and estimates for different scenarios of its future production as well as of the industry's need for forest raw materials for energy purposes in different scenarios. In the scenarios, lignin extraction for use outside of the pulp- and paper industry is estimated to increase from 0 TWh (baseline) to about 7 TWh in 2030 and 16 TWh in 2045. Tall oil production will remain at about 3 TWh in 2030 but increases to about 4 TWh in 2045. Together with smaller amounts of other byproducts (turpentine, lignosulfonate, ethanol), the sum of externally sold by-products from pulp- and paper industry increases from today's 4 TWh to about 11,5 TWh in 2030 and between 20 and 23 TWh in 2045.

AGRICULTURE-BASED RAW MATERIALS

Biomass from agriculture is used today to produce bioplastics. Examples of agriculture-based raw materials that can be used to produce bioplastics are corn, sugarcanes, potatoes and grains.[22] One challenge is that they often constitute primary raw materials, e.g. they can also be used as food or feed, which means that use for other purposes can be questioned. At the same time, there are side streams from agriculture that contain sugar, starch, or cellulose, all of which can constitute a good basis for further processing.[15] One example is straw that, today, is used for bedding material in animal husbandry, for energy production or left in the field to contribute to carbon sequestration and soil quality. Due to weather conditions and time constraints during harvest season it is not possible to harvest all the straw. Furthermore, straw left in the field or returned to the field contributes to carbon sequestration and soil quality. Taking weather constraints as well as needs for straw in animal husbandry and for soil quality preservation, the potential for use of straw for other purposes in Sweden is estimated to around 3.2 TWh per year.[23]

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[21] Energiforsk (2021). *Framtidsbild skogsindustrin – konkurrensen om den svenska skogsråvaran.* Energiforsk rapport 2021: 822. https://energiforsk.se/media/30668/framtidsbild-skogsindustrin-energiforskrapport-2021-822.pdf

[22] Brännström et al (2022). *Bioråvara till plast, nuläge och trender*. IVL Svenska Miljöinstitutet, rapport C 653. https://www.diva-portal.org/smash/get/diva2:1651150/FULLTEXT01.pdf

[23] Faktablad f3 (2025). *Feedstock for biofuel production - residues from agriculture.* f3 Innovation Cluster for Renewable Transport Fuels. https://f3centre.se/app/uploads/f3_restprod-jordbruk_eng_2025.pdf

MARINE-BASED RAW MATERIALS

Example of marine-based raw materials that can be used to produce bioplastics are macroalgae and microalgae. The potential of aquatic-based biomass is estimated to be rather small, around 1 TWh/year 2050.[24]

BIOGENIC FLOW OF WASTE

Example of biogenic flow of waste that can be used to produce bioplastics are used cooking oils, animal fat and residues from vegetable oil production processes.[18] A large share of these feedstocks are currently used for production of HVO. Another relevant biobased feedstock from waste is purified biogas (biomethane). According to the industry it would be possible to double the Swedish production of biomethane from today's 2 TWh to 4 TWh, with the same type of technology and waste sources as used today, and with an additional 2 TWh when using other sources.[25]

3.3 Suitability of feedstocks for plastic production

In 2024, a survey[26] directed towards academia, authorities, industry and industry organisations, was conducted to investigate opinions about available biobased raw materials and the suitability of using them for bioplastics. When asked which type of raw material that from a technical viewpoint is the most interesting or which they believe has the best potential in the future, most people identified lignin or other forest-based materials as most promising in the longer term, see Figure 5.[26] The question was limited to feedstock available in Sweden and Europe.

[24] Börjesson, P. (2021). *Potential för ökad tillförsel av inhemsk biomassa i en växande svensk bioekonomi – en uppdatering*. Avdelningen för miljö- och energisystem. Lunds universitet. https://lup.lub.lu.se/search/files/96470174/B_rjesson_P._2021._Rapport_nr_121_Milj_och_energisystem_Lunds_universitet.pdf

[25] Industrins Biogaskommission (2025) *Mer biogas till industrin! Åtgärdspaket för industrins materialomställning och konkurrenskraft* (More biogas for industry!, in Swedish). https://biogaskommissionen.se/Media/cyqh5yw4/mer-biogas-till-industrin.pdf

[26] Lagerstedt Eidrup, M.-L.; Ulmefors, H.; Hynynen, J. & Jedvert, K. (2024). *Möjliga värdekedjor för biobaserad plast – Slutrapport*. Chalmers Industriteknik. https://chalmersindustriteknik.se/app/uploads/Slutrapport-Final.pdf

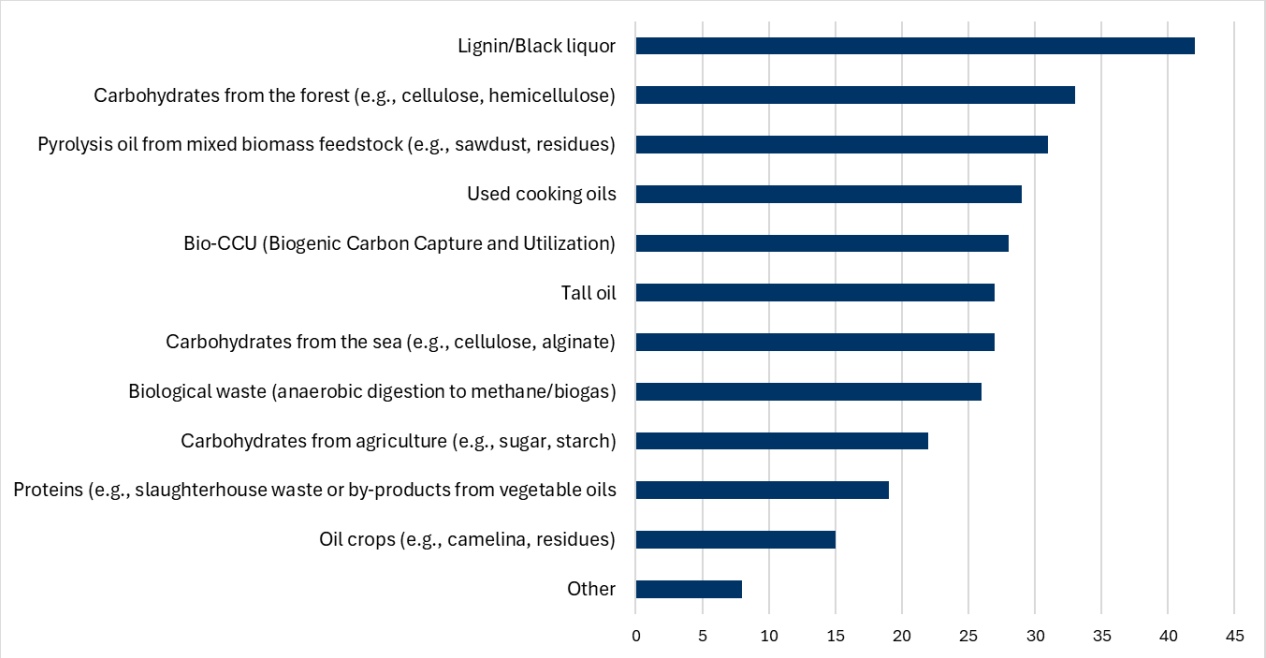

Figure 5 Result from the survey question: "Which raw material is best suited for the production of bio-based plastic?". Authors' translation of Swedish original in reference.[26]

A study published in 2019 [27] tried to answer whether biogenic waste from primary production, food industry, retail, distribution, and consumer food waste is physically available and practically applicable for use as feedstock to produce bio-chemicals through industrial fermentation in Sweden. The study stated that, if sufficiently uncontaminated, the waste from agriculture, postharvest, processing and distribution, can be used in secondary processes such as polymer production, while consumer waste generally can be assumed too contaminated for secondary processes, except for gasification. The conclusions on availability were simplified and summarized in two bullet points:

- The nearer primary production, the more homogenous, well defined waste streams and the higher the competition with other purposes – positive price and free market.
- The nearer consumers, the more inhomogeneous, variable, contaminated, impure and degraded waste streams and the lesser the competition with other purposes.

[27] Torén, J., Lorentzon, K. & Cintas, O. (2019). *Food waste as a resource for biobased chemicals and materials in Sweden (*rapport 2019:108). RISE Research Institutes of Sweden. https://ri.diva-portal.org/smash/get/diva2:1377549/FULLTEXT01.pdf

The question about which interesting waste streams, that also can be found in sufficient amounts, is a function of available production processes. Furthermore, the economic availability of feedstock was found to be governed by a multitude of factors, many of them political in nature. Given these conditions, the authors concluded that it is not likely that a development where food waste streams are used as feedstock for biochemicals will come about without incentives, support, and policy changes, even if this utilization leads to steps in a positive direction in the waste hierarchy.

The potential for biomass quoted above, focus – as noted – on the potential for bioenergy use. However, based on the scenario assumptions behind the scenarios of DGRI (2024)[17], one can conclude that the difference between their low and medium scenarios (in total corresponding to roughly 1000 TWh per year for the entire EU) is partly due to a strong increase in demand for biobased materials. As a very rough estimate, 1000 TWh of primary biomass would, depending on type of biomass and value chain, correspond to 40 Mton of plastics.[28]

The report Materials Economics (2021): EU Biomass Use in a Net-Zero Economy[41], concludes that there is a gap between what the industry has identified as their need of biomass for the transition to a biobased economy and the amount of available biomass (see Figure 6). The illustration clarifies the competition surrounding biomass and the need to prioritize and find new ways to efficiently use available resources. It should be noted, however, that even though the gap in Figure 6 is indicated in relation to the biomass demand for materials, there is no direct link to this usage. On the contrary, according to the cascading use of biomass principle, it is more likely that the gap would arise for biomass use for energy purposes. .

[28] Based on 60% efficiency from solid biomass to methanol, and about 40% efficiency from methanol to olefine.

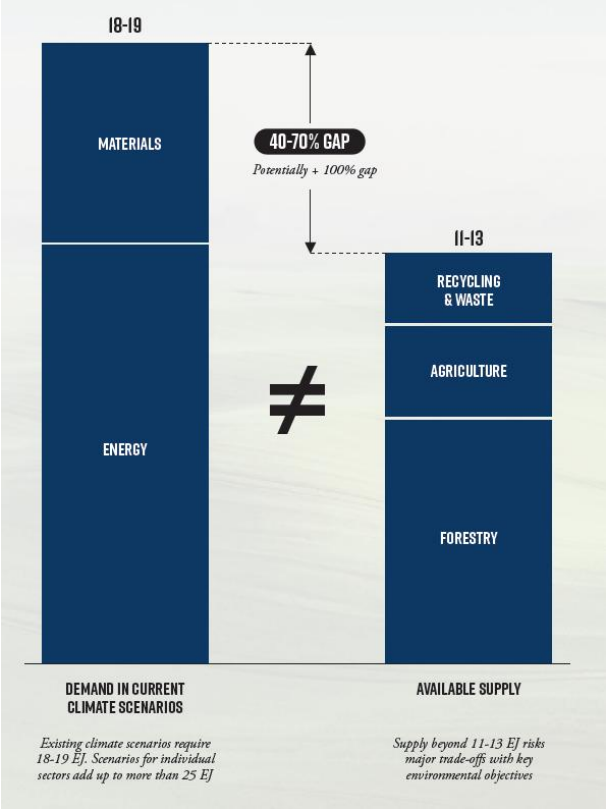

Figure 6 Scenario for future biomass supply and demand for materials and energy in the EU. (Primary energy equivalents in EJ per year, 13 EJ = 3600 TWh)[16]

4. Current related EU policies

The plastic industry faces a wide range of regulations, of which a large share is related to EU targets, strategies and initiatives that form the legal framework for transitioning into climate neutrality and a sustainable and competitive industry. It is beyond the scope of this study to give a complete overview of this policy landscape, since the focus here is restricted to the conditions for BBP.

European Bioplastics has given an overview of relevant EU legislation for bioplastics, as of 2023 (see Figure 7). Most of the policy frameworks, legalisation and legislative initiatives included in this overview relate to policies directed generally towards the climate, bioeconomy or plastics area. The ones more specifically focusing on the transition to sustainable plastic production and use are primarily directed towards policies for increasing the recycling of plastics and use of recycled feedstock in plastic production.

Formally, there are no legally binding policies in Sweden or the EU specifically targeting BBP. Within the EU Policy Framework on biobased, biodegradable and compostable plastics, the Commission has published an EC communication[29] that among other things state that use of biomass should align with the circular economy principles. This means that producers should prioritise the use of organic waste and by-products as feedstock, thus minimizing the use of primary biomass to avoid significant environmental impacts. When primary biomass is used, it is important to ensure that it is environmentally sustainable and does not harm biodiversity or ecosystem health.

Further it refers to the cascading use of biomass principle, and states that biomass should be preferably used to produce materials, including plastics, and only in subsidiary order, as a source of bioenergy. It also states that biomass used to produce BBP must meet the EU sustainability criteria for bioenergy, according to the *Renewable Energy Directive*[30] (RED or RED III, depending on context). However, with regards to greenhouse gas

[29] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (2022). *EU policy framework on biobased, biodegradable and compostable plastics.* COM(2022) 682. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022DC0682

[30] Unless explicitly stated otherwise, all references in this section are to the consolidated version of (EU) 2018/2001 dated 20.11.2023, i.e., the original REDII directive (EU) 2018/2001 with the changes introduced by (EU) 2022/759 and by the amending directive (EU) 2023/2413 (“RED III”)

emissions, they conclude that the bioenergy framework cannot be directly applied to BBP as these are not used to generate energy. They also refer to that methodologies to assess the impacts of BBP compared to fossil-based plastics from a life-cycle perspective are still under development. In this context they specifically mention the framework developed by the Commission's Joint Research Centre, referred to as the 'Plastics LCA method', which builds upon the EU Product Environmental Footprint (PEF) method as the most harmonised methodology currently available (see also Section 7.3).

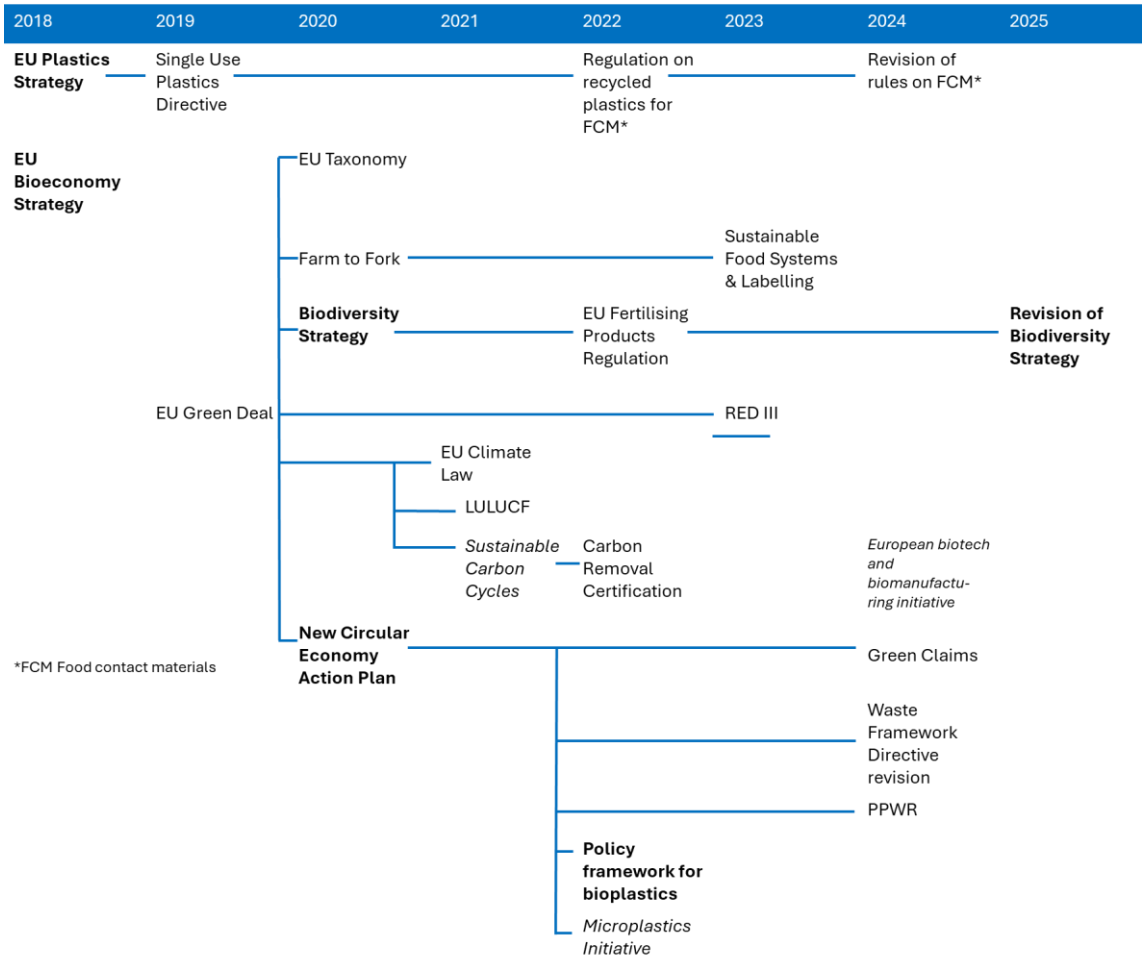

Figure 7 Overview of relevant EU legislation for bioplastics in 2025 (adapted from European Bioplastics[31]) Text in bold: Policy framework. Text in normal font: Legislation. Text in italic: legislative initiatives.

In addition, there are a few regulations of the plastic industry, that in the interviews and literature studied have been raised as potentially impacting

[31] European Bioplastics (2025). *Overview of relevant legislation for bioplastics.* https://www.european-bioplastics.org/policy/. (Accessed 2025-11-25)

the development of biobased plastic policies. Therefore, the roles of these are shortly described below. These include primarily the Packaging & Packaging Waste Regulation (PPWR), the Ecodesign for sustainable products regulation (ESPR) and the Sustainable Taxonomy.

In the remainder of this report, the focus is on policy measures that are strictly focusing on the use of biomass to produce plastics, partly in relation to criteria for safeguarding the sustainability of used feedstock (Chapters 6 and 7), partly in relation to policies specifically introduced to advance the use of (sustainable) biobased feedstock (Chapter 8).

4.1 The Packaging and Packaging Waste Regulation

The *Packaging and Packaging Waste Regulation*, PPWR[32], aims to reduce environmental impact by promoting sustainable packaging, minimizing waste, and fostering a circular economy across the EU. It ensures that packaging is designed, used, and managed in ways that protect both consumers and the planet. Being a regulation implies that member states cannot introduce other substantive requirements beyond what is in the EU regulation. They can only act in areas left open by the regulation, such as enforcement, penalties, or practical implementation.

The regulation addresses the entire packaging life cycle and some of the key provisions are:

- All packaging must be reusable or recyclable, 2030.
- Plastic packaging must contain a minimum threshold of recycled material.

According to the regulation there are currently no requirements that BBP are to be used, however the regulation describes that in the cases where virgin material is required, BBP constitute a relevant alternative. Moreover, the regulation requires that also BBP in packaging shall be recyclable.

Further, the use of BBP should be further regulated from 2028. Article 8.1 of the regulation stipulates that:

> *By 12 February 2028, the Commission shall review the state of technological development and environmental performance of*

[32] Regulation (EU) 2025/40 of the European Parliament and of the Council of 19 December 2024 on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202500040

> *biobased plastic packaging, taking into consideration the sustainability criteria [in the RED]*
>
> *Based on the review […] the Commission shall, where appropriate, present a legislative proposal in order to […] lay down sustainability requirements for biobased feedstock in plastic packaging.*

The EC Directorate-General för Environment (DG-ENV) has in the fall of 2025 initiated an investigation aiming at detailing the implementation of Article 8.1. The study will be carried out with support by the EC Joint Research Centre (JRC) and is expected to be finalized in the spring 2027.

Earlier drafts of the PPWR contained stricter wording about how biobased content must be physically present. In the final adopted regulation, Article 8 is instead a review clause — meaning that the Commission will decide later (by 2028) whether to set binding sustainability requirements, targets, or definitions. This means that today and until the new revision of article 8 is in place, mass balance is not approved as biobased content.

4.2 Ecodesign for Sustainable Products

The *Ecodesign for Sustainable Products Regulation* (ESPR) [33] came into force in July 2024. Through delegated acts, this policy will, in the long term, include almost all product categories. The Commission adopted the first ESPR and Energy Labelling Working Plan in April 2025[34], setting out which products will be prioritised over the coming years. In this plan, which was supported by preparing studies carried out by JRC, the Commission concludes:

> *The product group 'chemicals' was highly ranked in the JRC study in terms of high impacts and high improvement potential. The open public consultation also found support to include chemicals in the list, but it is a very complex product group that the JRC study assessed as an intermediate product, focusing on large-volume organic and inorganic chemicals. However, the scope of the chemicals product group is commonly understood to be much wider, and there is an*

[33] Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401781

[34] Communication from the Commission. Ecodesign for Sustainable Products and Energy Labelling Working Plan 2025-2030. COM(2025) 187. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52025DC0187

overlap with other segments such as petrochemicals, polymers, specialty chemicals and plastics. Given this complexity, a study will be launched by the end of 2025 to define more precisely the potential chemicals in scope as well as a potential focus area(s) for product aspect improvements for (a) future ESPR delegated act(s) related to chemicals (including polymers & plastics) to be considered for inclusion in the review of this or in a following working plan.

ESPR does not distinguish between biobased and other products – they are assessed based on product aspects, e.g. durability, reliability, reusability, upgradability, repairability, resource use and resource efficiency, and environmental impacts, including carbon footprint and environmental footprint. However, some parameters may be used to establish product group performance requirements, e.g. its use or content of sustainable, renewable material. If this will be the case, the member states are not allowed to introduce other requirements than these, as this would violate the principles of free movement of goods and services on the inner market.

ESPR stipulates that, when preparing eco-design requirements, the Commission shall ensure consistency with other Union law and shall take into consideration relevant technical information used as a basis for or derived from Union law or instruments[35]. Information about products' sustainability will be included in a Digital Product Passport (DPP), a digital identity card for products, components, and material. Information to be included in the DPP will be identified by the Commission, in close consultation with all relevant stakeholders, and will depend on the specific product in question. [33]

In the ESPR and Energy Labelling Working Plan 2025-2030[34] from April 2025, the EC communicates that the specific situation of intermediate products needs to be considered when setting ecodesign requirements. In the context of the current study, polymers and plastics could qualify as intermediate products in many supply chains. The EC stresses that regulating intermediate products could have consequences not only on their manufacturing but also on all final products made from them, and that the potential impact on relevant markets needs careful assessment to avoid negative downstream consequences. These assessments are yet to be carried out.

[35] Including instruments such as: Regulation (EC) No 66/2010 (about the EU Ecolabel), Directive 2010/75/EU (about industrial emissions), technical screening criteria adopted pursuant to Regulation (EU) 2020/852 (about a taxonomy for sustainable investments) and EU green public procurement (GPP) criteria.

The EC has the possibility to combine Green Public Procurement (GPP) and ESPR in a delegated act, including mandatory GPP: This would mean that public procurers only can buy products with a specific sustainability performance within a product category. The ESPR is not clear on how this kind of requirements will be designed, but it is likely that performance needs to be measurable so that products can be ranked based on different parameters (energy use, recycled content etc.)[36].

4.3 The Sustainable Taxonomy

The Sustainable Taxonomy Regulation[37] (below "the taxonomy") is included in the EU's sustainable finance framework. It is a classification system that defines criteria for economic activities that are aligned with a net zero trajectory by 2050 and the broader environmental goals than climate.

The taxonomy states that an economic activity shall qualify as contributing substantially to the transition to a circular economy when that activity e.g. uses natural resources, including sustainably sourced biobased and other raw materials. It also states that criteria for 'do no significant harm' (DNSH) should ensure that the economic activity has no significant negative environmental impacts, including climate-related impacts. In the supplementing delegated regulation[38], technical screening criteria for determining the conditions under which an economic activity complies with the taxonomy are found. In the context of this report, two economic activities are relevant:

- **Manufacture of plastic packaging goods**: For the manufacture of plastic packaging goods, one criterion of three optional criteria to be met consists of using bio-waste feedstock: at least 65 % of the packaging product by weight consists of bio-waste feedstock that

[36] Naturvårdsverket (2025). *EU-förordningen om ekodesign för hållbara produkter (ESPR)* https://www.naturvardsverket.se/amnesomraden/cirkular-ekonomi/eu-forordningen-om-ekodesign-for-hallbara-produkter-espr/. (Accessed 2025-11-01)

[37] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0852

[38] Commission delegated regulation (EU) 2023/2486 of 27 June 2023 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to the sustainable use and protection of water and marine resources, to the transition to a circular economy, to pollution prevention and control, or to the protection and restoration of biodiversity and ecosystems and for determining whether that economic activity causes no significant harm to any of the other environmental objectives and amending Commission Delegated Regulation (EU) 2021/2178 as regards specific public disclosures for those economic activities. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302486

complies with the criteria in REDIII Article 29 paragraph 2-5 or 6 and 7 (see 6.2). The taxonomy also states that the criteria for 'do no significant harm' (DNSH) should ensure that the economic activity has no significant negative environmental impacts, including climate-related impacts. The DNSH criteria state e.g. that life cycle GHG emissions of plastic manufactured from such bio-waste feedstock are lower than the life-cycle GHG emissions of the equivalent plastics in primary form manufactured from fossil fuel feedstock, calculated and third party verified using one of three given alternative methods: the Product Environmental Footprint method[39], ISO 14067:2018 Greenhouse gases — Carbon footprint of products[40] or ISO 14064-1:2018 Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals[41].

- **Construction of real estate activities**: In the construction of new buildings, criteria include that use of primary raw material is minimised using secondary raw materials and that the operator ensures that the three heaviest material categories used (in kilogrammes), comply with stated maximum total amounts of primary raw material used. For biobased materials[42], a maximum of 80 % of the total material comes from primary raw material. For non-biobased plastic, a maximum of 50 % of the total material comes from primary raw material. In the renovation of existing buildings, the equivalent figures for the three heaviest material categories added to the building in the renovation are 90% and 75% respectively.

[39] Commission recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32013H0179

[40] ISO 14067:2018. *Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification.* https://www.iso.org/standard/71206.html

[41] ISO 14064:2018. *Greenhouse gases. Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.* https://www.iso.org/standard/66453.html

[42] The Taxonomy definition: "Bio-based materials are made using biological resources. They include conventional bio-based materials made traditionally from biomass (such as wood, cork, natural rubber, paper, textiles, wooden construction materials) and more recently developed materials such as bio-based chemicals or bio-based plastics." (Page 53, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302486)

5. Positions from stakeholders

5.1 Published positions

EUROPEAN BIOPLASTICS

In position papers from June and September 2025, the European association for the bioplastics industry, European Bioplastics (EUBP), explains its standpoint on industrial use of agricultural materials as feedstock for BBP[43] and sustainability criteria for biomass[44]. The association agrees with the Commission on the necessity of laying down suitable sustainability criteria, but argues that they must be combined with market pull measures such as the introduction of mandatory biobased content targets in industry sectors. Furthermore, EUBP believes that industry needs a legal and regulatory framework that allows for the use or uptake of biomaterials in the same way as for bioenergy production; currently, the bioenergy sector is promoted through different robust legislative measures, whereas the bioplastics industry lacks such support.

Earlier, in their comments on the EU policy framework on biobased, biodegradable and compostable plastics[45] from 2022, EUBP suggests that the Commission should promote a minimum biobased content to the same extent as recycled content in plastic products as is the case in PPWR. EUBP points out that when communicating with consumers, claims on 'biobased' plastics should refer to the share of biobased content in the product. Furthermore, EUBP argues that claims on the biobased (carbon) content of a plastic product in B2C communication can only be made based on calculations using the C14-method in line with European standards and using independent, third-party certification schemes for biobased content. EUBP criticises the Product Environmental Footprint (PEF) and the JRC's Plastics LCA methods (see Section 7.3), for not giving any recognised

[43] European Bioplastics (2025). *Industrial use of agricultural materials as feedstock for biobased plastics.* https://docs.european-bioplastics.org/publications/pp/2025/EUBP_PP_Industrial_use_of_agricultural_materials_as_feedstock_for_biobased_plastics.pdf

[44] European Bioplastics (2025). *Sustainability Criteria for Biomass.* https://docs.european-bioplastics.org/publications/pp/2025/EUBP_PP_Sustainability_Criteria_for_Biomass.pdf

[45] European Bioplastics (2023). *EU policy framework on biobased, biodegradable and compostable plastics.* https://docs.european-bioplastics.org/publications/pp/EUBP_Statement_Policy_framework_biobased_biodegradable_and_compostable_plastics.pdf

benefit for the use of biogenic carbon at the beginning of the product life cycle and/or for biogenic carbon uptake. Instead, EUBP and other European industrial organisations, suggests an updated method[46] that awards a carbon bonus at the stage of its uptake and giving a carbon malus when it is released back into the atmosphere. The net effect of such a system would in principle correspond to the carbon bonus (zero for fossil resources) for biobased feedstocks, while it includes an additional benefit for long-term material use and recycling compared to use as energy (avoiding the carbon malus, which would be similar for both biobased and fossil feedstocks).

RECYCLING EUROPE

Before the adoption of the Packaging and Packaging Waste Regulation (PPWR), the European Recycling Industries' Confederation (EuRIC) presented six key recommendations for making packaging more circular under the PPWR. One of these was that recycled content and BBP deserve separate targets. The organisation argued that linking biobased-and recycled content incorporation targets would heavily undermine the scope of recycled content targets. Furthermore, biobased plastic content should only replace virgin plastic content.[47]

THE INNOVATION AND CHEMICAL INDUSTRIES, IKEM

In the autumn of 2024, the federations IKEM (the Innovation and Chemical Industries) and Lif (the Researching Pharmaceutical Companies) launched a Roadmap for Climate Neutral Competitiveness as part of the initiative Fossilfritt Sverige[48].

The chemical industry specifically mentions biobased raw materials as an important contribution to achieve climate neutrality.

For the plastic industry the goals are defined as by 2030 the plastic waste entering the material recycling system shall be doubled compared to current levels and by 2040 the level shall reach 80%. Hence, the plastic industry is not focusing on increased utilization of biomass but rather to ensure recycling by investments in recycling systems, design for recycling and

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[46] European Biobplastics (2022). *Towards an accurate accounting for carbon from biomass in the Product Environmental Footprint (PEF).* https://docs.european-bioplastics.org/publications/Coalition_Paper_Towards_an_accurate_accounting_for_carbon_from_biomass_in_the_Product_Environmental_Footprint_PEF.pdf

[47] Recycling Europe (2023). *Reycler's 6 key recommendations for improving packaging circularity under PPWR*. https://euric.org/resource-hub/public-consultations/recyclers-6-key-recommendations-for-improving-packaging-circularity-under-ppwr. (Accessed 2025-11-01)

[48] Fossilfritt Sverige (2024). *Roadmap for climate-neutral competitiveness. The Innovation and Chemical Industries.* https://fossilfrittsverige.se/wp-content/uploads/2025/09/ffs-ikem-english-2.pdf

utilization of recycled material. The roadmap stresses the need for biobased materials at competitive prices and in large enough quantities.

The interview with representatives from IKEM made clear that the chemical industry would like distinct sustainability criteria for biobased feedstock to be used e.g. in public procurement. In IKEM's position statement response to the European Bioeconomy Strategy[49] , the organization recommends Article 29 in RED III as a starting point for the development of such criteria. Harmonized sustainability criteria should also consider biodiversity through other relevant legislation, e.g. EU Biodiversity Strategy for 2030, commitments in the Kunming Montreal Framework and the Nature Restoration Law, the LULUCF Regulation, as well as criteria under the EU Taxonomy Regulation.

INDUSTRINS BIOGASKOMMISSION

Industrins Biogaskommission (biogas commission representing various industries) is focusing on industry-access to biogas as a raw material. The commission has estimated the total demand for biogas from the Swedish industry to 10 TWh by 2030. About 6 TWh of this corresponds to the expected demand for biogas as raw material for metallurgical processes and chemical products. The organization does not express any position regarding sustainability criteria for use of biogas as raw material. A reason for this could be that biogas producers, primarily delivered as biofuel, are used to the RED III sustainability criteria, and that they easily comply with these (biogas being produced from waste with high GHG emission reductions).[50]

5.2 Input from stakeholder contacts and interviews

Stakeholders in the value chain, trade organisation Skogsindustrierna, IKEM and European Bioplastics, producers of polymers Borealis and Inovyn, Emballator producer of plastic packaging, the recycler Svensk Plaståtervinning and the Directorate-General for Environment, DG-ENV, within the European Commission, supporting and drafting regulatory

[49] IKEM (2025). *Position Statement Response to the European Commission's Call for Evidence: "Towards a Circular, Regenerative and Competitive Bioeconomy"*. https://www.ikem.se/fragor-vi-driver/remissvar/ikem-position-statement-response-to-the-european-commissions-call-for-evidence-towards-a-circular-regenerative-and-competitive-bioeconomy/

[50] Industrins Biogaskommission (2025) *Mer biogas till industrin! Åtgärdspaket för industrins materialomställning och konkurrenskraft* (More biogas for industry!, in Swedish). https://biogaskommissionen.se/Media/cygh5yw4/mer-biogas-till-industrin.pdf

documents, were interviewed during the project (see also Appendix 1). Their input has been summarised below.

The overall vision within EU to increase the amount of BBP in the system is directly connected to the production of the same, which in turn is impacted by the demand of the biobased alternatives from the market. Generally, the perception among the interviewees is that the price for the biobased alternatives is somewhere between 50-100% higher. The majority of all plastic materials are used in low-end products i.e packaging, where the price of the product is directly connected to the price of the material, hence if the plastic material is 50% more expensive the product will also be 50% more expensive. In more exclusive products where further processing have been done the cost is more distributed and the material cost is therefore more diluted. Thus, irrespective of the increasing interest for the biobased alternatives, it is clear that money talks and the "willingness to pay" for a simple but more costly product is low, says all interviewees.

It is challenging to overcome this hurdle as, according to the producers, the price is related both to the cost of the biobased raw material and to the efficiency of the process and the quantity produced. According to the producers the price of the biomass is strongly exposed to harsh competition from the increased need for bio-based fuel where the fuel industry has more binding regulations and, as a result, is less price sensitive. Further, it has to be noted that producing bio-based plastic includes more process steps than production of biofuels, contributing to the increased price.

To partly overcome this the plastic industry – just as the biofuel industry - is investigating other raw material sources than primary, partly to follow recommendations from the EU to avoid conflict with other interests like food and feed, but also to secure the input of raw material for their processes. However, these alternative sources are often scattered small volumes that entails logistic challenges, unstable deliveries and insufficient quantities for the plastic industry and their needs. The plastic industry therefore strongly urges the acceptance of mass balance in the transition to a biobased industry.

Mass balance certificates require traceability, meaning that if to claim biobased content in a product the full value chain has to be certified according to the same standard. Certification, being a costly and challenging procedure, creates an aversion among many companies to join the scheme, preventing them from claiming mass balanced content. According to the producers this further reduces the speed of transition to biobased alternatives.

The main regulation in focus for both the producers and converters is the PPWR[51], mainly due to the fact that packaging are the dominant applications of plastic materials. In this regulation, the focus is more on utilization of recirculated material than biobased. Moreover, according to the industry, mass balanced material is not approved by the PPWR, leading to similar obstacles affecting the transition of the industry. However, in parallel, the industry foresees that biobased will be the only alternative where other regulations require virgin material or where the higher price can be defended by a more premium product.

Within the DG-ENV, work has started to update article 8 of the PPWR regulation. The work will thus include development of sustainability criteria and targets for BBP in *packaging*, and is intended to be finalised within a year and a half. The work takes off in earlier workshops and input from stakeholders, during the last 3-4 years, and will continue during 2026 with more workshops. The intention is to ensure that the update is well anchored when implemented.

The sustainability criteria will be based on RED III and will need to take the coming revisions of RED in 2027 into account. The most challenging part is expected to be to set relevant targets (formulated in percentage biobased content) and the GHG emission calculations, which need to be developed to ensure recycling give environmental benefit. The methodology will build on RED in combination with Product Environmental Footprint, PEF, and consider possibilities to include mass balancing. DG-ENV at this point is not focusing on adding sustainability requirements on the biobased raw material used.

Further, according to some of the interviewees the Environmental Product Declaration, EPD, a standardized report on a product's environmental impact, commonly used for construction products (see 6.3.4), does also not accept mass balance as a method, thus reducing the interest of introducing the material and decreasing the demand.

Irrespective of the challenges for the plastic producers they are positively disposed to sustainability criteria, which is also valid for their customers. The general comments are, firstly, that if it works for the fuel industry it works for the plastic industry and, secondly, that it is important that we do not create more damage to our environment by increased extraction of biomass as raw material for plastics.

[51] Regulation (EU) 2025/40 of the European Parliament and of the Council of 19 December 2024 on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202500040

The Swedish Forest industry, is generally positive to sustainability criteria but opposes to introducing the RED III criteria on biomass for other purposes than fuels. The organisation argues that, today, there are other policies in place for the use of by-products from forestry (Regulation on Deforestation-free Products, Nature Restoration Regulation, the Land use, land-use change and forestry Regulation (LULUCF) and several voluntary schemes) and adding RED criteria would likely cause dual regulation. Furthermore, there are still a number of unsolved issues, delays and implementation difficulties in connection to RED, and uncertainties are always a nuisance to industry and might interrupt or postpone investments. From their point-of-view, Nordic forestry already has a high profile in terms of sustainability, and therefore they are not supporting additional regulations like the RED III for use of forestry resources[52].

Both the packaging industry and the recycling companies insist on that the plastic material in all products put on the market must be recyclable irrespective of its origin. This is both due to the need of recycled volumes to be used in new products but also that recycling is a resource efficient and sustainable way of producing plastics. Increased recycling, also of the BBP, is crucial to ensure that the availability of the biobased raw material is sufficient and does not become a bottleneck.

To strengthen the motivation to increase the production and use of BBP obstacles in the form of contradictions in regulations or a too complex regulatory landscape have to be opposed by the regulating authorities. It was suggested during the interviews that it might be beneficial to commence with a few, simple regulations and learn as we go.

To support the transition to more BBP according to the interviewees, are to introduce policies, like requirements on biobased content in products. But, as the main hurdle seems to be the higher price for biobased raw materials, the approach of subsidizing or adding costs to the fossil-based alternatives should also be considered.

The biobased plastic industry only constitutes about 1% of the global plastic market. To enable a durable growth of the business, it is vital that regulations have a long-term perspective, supporting the transition step-by-step, supporting the industry to overcome the hurdles and obstacles they face.

[52] The revision of the RED into RED III, involved an update of sustainability criteria for forest biomass. The Swedish implementation of these will come into force from December 1st, 2025. Consequently, there are still many uncertainties about how the new criteria will affect the Swedish forestry.

6. Current use of sustainability criteria for biomass feedstock

6.1 Principles for and use of sustainability criteria

Sustainability criteria can be described as a set of rules that help decide what is and isn't considered sustainable. Their purpose is to safeguard resources against unsustainable use and to provide transparency to sustainability claims made regarding products, processes and services – i.e., a product, process or service that is claimed as sustainable according to a certain legislation or certification shall comply with the criteria of that legislation or scheme.

Sustainability criteria are in general used in three different contexts:

- First, voluntary as part of a company strategy, i.e. a company that sets targets for the use of more renewable feedstocks or energy, that should be met without compromising sustainability. The adoption can also be the result of demands from public and private customers. For credibility reasons, sustainability claims are most often verified by some kind of certification scheme or standard.
- Second, after further "endorsement" of a specific set of sustainability criteria by the authorities, which may link them to public procurement, the possibility to apply for public financing or just to be able to put an official "sustainability stamp" on the products. This is in some respects similar to when public customers set sustainability requirements. Here, however, the actual criteria that should be met and the method for verification that should be used are specified by the (mostly national, or EU) authorities.
- Third, the sustainability criteria are linked to legally binding regulations, in which the adoption of the criteria is required to be eligible for tax reductions, or other general policy measures (e.g. quota systems).

In general, the development of sustainability criteria will include a trade-off between the desire to ensure sustainable resource utilisation and practical aspects such as, e.g., limiting the compliance burden of actors affected by the criteria and the resources needed for follow-up and control by authorities or other control agencies. Another trade-off is between ensuring that use of

clearly unsustainable biogenic resources is avoided at the same time as the criteria do not hinder the transition from even less sustainable and easily accessible fossil alternatives.

Depending on the scope of the legislation or certification scheme that define them, sustainability criteria may cover different aspects of sustainability, i.e., one or more of the three dimensions of sustainability: ecological (preservation of the carrying capacity of ecosystems), economic (economic growth that doesn't conflict with the other dimensions), and social (the ability to fulfil human needs at a global level). The sustainability criteria discussed in this study, focus on various aspects of ecological, and to some extent, social sustainability. The various aspects can be categorized differently, but generally include aspects related to:

- Land use and land use change (direct and indirect).
- Biodiversity.
- Resource efficiency.
- GHG emissions.
- Other emissions to air, water and soil.
- Ecotoxicity, human toxicity.
- Social responsibility aspects, including e.g. human rights and employment conditions (such as requirements of a "living wage" and bans on involuntary and child labour).

Sustainability criteria for biomass utilisation were first introduced in EU legislation in relation to biofuel production (and later bioenergy) and covered (parts of) the ecological dimension of sustainability. Further, they are especially designed to safeguard the sustainability when virgin biomass, *not* from waste or residues, are utilized. For these purposes legally binding criteria have been used since 2008.

The EU biofuel and bioenergy sustainability criteria have since been developed and adjusted through several lengthy legislative processes and are now included in the latest version of the RED (RED III) – still only covering the ecological dimension of sustainability.

It should be noted that sustainability criteria do in general not include aspects directly linked to the amount or share of biobased content, which is often in focus for company communication and different types of policy measures (e.g., biofuel blend mandates). GHG emission reduction calculations (often included in sustainability criteria) do, however, indirectly require principles for calculation of the volume of biobased product and/or the share of biobased content. .

In relation to determining the biobased content there are different principles, that can broadly be divided between those that focus on the physical biobased content in a specific final product, and those that rely on mass

balance principles. Further, the "level" of mass balancing that is allowed under different criteria and schemes differ, which complicates the picture further.[53] It is outside the scope of this study to go deeper into the different methods for determining biobased content, but it is to some extent further discussed in Chapter 7.

6.2 Sustainability and GHG criteria in RED III

6.2.1 Legal structure and applicability

RED III[54] defines sustainability criteria for biofuels, liquid biofuels, and biomass fuels[55], which must be met for such fuels to be categorized as renewable fuels that can be counted towards the targets of the Directive. The member states, that are responsible for fulfilling the targets, have the choice of designing and introducing various policy measures (such as reduction quota, tax schemes etc) to reach them. However, only biofuels that fulfil the criteria can be eligible for financial support (i.e. be included in policy measures that support the transition to biofuels). There is no direct ban on producing biofuels from (according to the criteria) unsustainable biomass. However, through the linkage to mandatory targets and policy measures, there are no biofuels on the market that have not been approved according to the criteria.

As noted above, the RED III criteria are entirely focused on the ecological aspects of sustainability; they do not include aspects related to economic or social sustainability. In the directive the criteria are denoted partly as "sustainability criteria", partly as "criteria for GHG emissions savings". The former focus on prohibiting use of biomass from specific land types (see Section 5.2.2). To avoid confusing this set of criteria with the broader use of the term "sustainability criteria" above, we have chosen to use the term *land*

[53] For more detail, see for instance Nyström et al (2020) *Standards and certification schemes related to the mass balance approach – Applications in chemical industry*. CIT Industriell Energi. https://klimatledande.lindholmen.se/sites/default/files/2024-01/report_mass-balance_approved_200406_3.pdf

[54] Unless explicitly stated otherwise, all references in this section are to the consolidated version of (EU) 2018/2001 dated 20.11.2023, i.e., the original REDII directive (EU) 2018/2001 with the changes introduced by (EU) 2022/759 and by the amending directive (EU) 2023/2413 ("RED III")

[55] Below, the three categories are jointly referred to as "biofuels", which then include both biofuels for transportation and for heat and power production. Criteria are also included for renewable hydrogen and its derivatives (renewable fuels of non-biological origin or RFNBOs), and recycled carbon fuels (RCF). The latter fuel types are, however, not further discussed in this report.

use related criteria[56] below. The land use related sustainability criteria for biofuels are described in Article 29.2–7 of RED III. In addition to the sustainability criteria, Article 29.10 contains criteria for greenhouse gas (GHG) emissions savings, which also must be fulfilled by fuels counted towards the targets of the directive.

It should be noted that none of the criteria require the biomass feedstock to be a waste or residue, i.e., "virgin" biomass can be used for biofuel production under REDIII. However, biofuels produced from waste and residues, other than agricultural, aquaculture, fisheries, and forestry residues, are exempt from the land use related sustainability criteria (but not from the GHG emissions' savings criteria). Further, production of biofuels from waste and residues is favoured by specific sub-targets in the Directive and by (generally) achieving higher GHG emissions' savings under REDIII GHG-calculation methodology (see section 6.2.3).

All regulation in RED III, aiming at steering towards (or from) specific types of biofuels or raw materials are thus not included in the sustainability criteria, but rather in the setting and formulations of targets and shares of biofuels. For example, the contribution of biofuels based on food and feed crops towards the renewable energy targets is limited at a maximum of seven percentage points of final consumption of energy use in the transport sector. The share of high indirect land-use change-risk biofuels produced from food and feed crops, cannot increase compared to the level of 2019 and should gradually decrease from 2023, to 0 % by 2030.[57]

The responsibility to verify that the sustainability criteria are met lies on the economic organizations (companies) that produce and/or put the biofuels on the market of each member state. Normally, and in Sweden, the responsible organizations are the companies that pay fuel taxes. They are then responsible to trace and control the biomass feedstock, through certified control systems for the entire delivery chain. For this purpose, the EU has identified certification schemes that are officially recognized for certifying the compliance with the criteria (see further Section 6.3.1).

Fulfilment of the RED III sustainability criteria, both the land use and GHG emissions' savings criteria, is also a requirement for eligibility or compliance with several *other* EU legal acts currently in force. For example, it is a requirement for zero-rating of emissions from the use of biofuels

[56] The choice of these criteria is based on various aspects, including preservation of soil carbon and biodiversity.

[57] For a summary of REDIII targets and sustainability criteria, see also Faktablad f3 (2024). *Mål och hållbarhetskriterier för förnybara drivmedel i EU:s förnybartdirektiv.* f3 Innovation Cluster for Renewable Transport Fuels. https://f3centre.se/app/uploads/f3_faktablad-5-2024_Styrmedel-EU.pdf (in Swedish)

under the EU Emissions Trading System (EU ETS), for the production and use of biofuels to be eligible for state aid under, e.g., the General Block Exemption Regulation, for bioenergy-related activities to be taxonomy-aligned, and for biofuels to be eligible under *ReFuelEU Aviation*[58] and *FuelEU Maritime*[59]. Future legislation may also apply the sustainability criteria of the RED for BBP in packaging (see Section 4.1 on PPWR).

6.2.2 Land use related criteria

In RED, land use related sustainability criteria were developed to protect land with high environmental values (e.g., high carbon stocks, soil quality or biodiversity) from harvest and extraction that would impact those values. To this end, the criteria specify 1) what kinds of biomass may be used to produce biofuels and 2) how that biomass may be sourced. The first aspect is regulated by prohibiting biomass sourcing from land types that are considered environmentally valuable and/or sensitive. The second aspect, by specifying rules for harvesting practices and land management. In some cases, prohibited land types may be used for biomass sourcing if compliance with certain harvesting practices or managements systems can be demonstrated.

The criteria are summarized below[60].

Criterion 1 (Article 29.2):

This criterion applies to waste and residues from agricultural land. Such biomass may only be used for biofuel production if the land from where it is sourced is subject to monitoring or management plans addressing impacts on soil quality and soil carbon.

Criteria 2–4 (Article 29.3–5):

These criteria apply to agricultural biomass. Such biomass may not be used for biofuel production if it is sourced from land:

- with a high biodiversity value
- with high-carbon stock
- that was peatland in January 2008

[58] Regulation (EU) 2023/2405 of the European Parliament and of the Council of 18 October 2023 on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302405

[59] Regulation (EU) 2023/1805 of the European Parliament and of the Council of 13 September 2023 on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1805

[60] Note that this is a summary intended to give an overview of the content of the criteria. Always refer to the cited articles of the directive for details and context.

In several cases, biomass from prohibited land types can be used if evidence is provided to show that biomass extraction does not interfere with environmental values. E.g., agricultural biomass from land that was previously peatland can be used if "*evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil*".

Criteria 5–6 (Article 29.6–7):

These criteria apply to forest biomass. They state that:

- The three land types prohibited for agricultural biomass extraction are largely also prohibited for forest biomass extraction (although some subcategories of the first two land types are allowed for forest biomass extraction).
- Forestry on permissible land types must comply with various harvesting rules, including maintaining or enhancing the forest's long-term production capacity and taking into account soil quality and biodiversity.
- Compliance with the above points in the harvesting area must be ensured either by the existence of national/sub-national legislation combined with monitoring and enforcement systems or by management systems.
- The LULUCF-criteria laid out in 29.7 must be followed. These imply that mechanisms must exist in the harvesting area to ensure that carbon stocks and sinks are maintained or enhanced or changes in carbon stock associated with biomass harvest must be accounted for in the country of origin's commitment to reduce or limit greenhouse gas emissions under the Paris Agreement.

6.2.3 Greenhouse gas emissions savings criteria

In addition to the land use related criteria above, biofuels must achieve certain GHG emissions savings thresholds to be counted towards the targets of the RED. The thresholds are defined in article 29.10 and differ depending on fuel type, its application, and the commissioning date of the plant that produces the fuel (or use it, depending on fuel type)[61].

Greenhouse gas emissions from the production and use of the biofuel shall be calculated according to the methodology set out in Annexes V and VI of the directive (and further described below). The GHG emissions are calculated *per unit* of biofuel produced. The GHG emissions savings from

[61] The regulations are linked to commissioning date, since the GHG emissions partly relate to plant efficiency. Therefore, less demanding regulations are imposed on already existing plants, than on newly built ones. This stepwise approach contributes to decreasing the risk for de-commissioning of existing plants and reductions in production capacities.

the use of the biofuel shall then be calculated by comparing the resulting emissions to the fossil comparators that are also defined in the annexes.

The GHG emission calculations of the directive uses a "well-to-x" methodology to determine emissions, according to the following formula:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr},$$

Simply put, the calculation includes all GHG emissions[62] along the value chain that produces the fuel, consisting of emissions from:

- extraction or cultivation of feedstock (e_{ee}),
- carbon stock changes caused by land use change (e_l),
- processing (e_p)
- transport and distribution of feedstock (e_{td}), and
- fuel in use (e_u)

In addition, the fuel can receive credits for CO_2 soil carbon accumulation resulting from improved agricultural management (e_{scs}), and for CO_2 capture and storage or replacement (e_{ccs} and e_{ccr}).[63]. Direct CO_2 emissions from the use phase for the biofuels (e_u) are set to zero, since there is no factor taking uptake of CO_2 in the growth phase into account.

Wastes and residues used as feedstock are considered to have zero emissions up to the point of collection (i.e. all emissions prior to the collection of the waste are allocated entirely to the primary use of the biomass). This means that, in general, only emissions linked to processing and transport and distribution of the feedstock is taken into account.

GHG emissions from biofuel production based on virgin crops thus include emissions from feedstock farming (fuel use in machinery and direct land use emissions) as well as all processing and transportation steps. The same biofuel produced from food industry waste (for instance waste bread), only include emissions from the waste collection from the bakery (or grocery stores) and from the processing (which normally entails fewer process steps) and transportation from that point.

The calculation does not include emissions from the construction and decommissioning of infrastructure, production plants and equipment.

Total emissions are then compared from to the fossil comparators, for corresponding fuel use. The following fossil fuel comparators (Annexes V

[62] CO_2, N_2O and CH_4

[63] For bioenergy (heat and electricity) some more specific calculation principles are included.

and VI) and emission savings thresholds (article 29.10)[64] are defined in the directive:

- Biofuels and biogas used in the transportation sector
  - Threshold: at least 65 % reduction
  - Comparator: 94 $gCO_2eq./MJ_{\mathbf{fuel}}$
- Bioliquids used to produce electricity, heating and/or cooling
  - Threshold: at least 65 % reduction
  - Comparators: 183 $gCO_2eq./MJ_{\mathbf{electricity}}$ and 80 $gCO_2eq./MJ_{\mathbf{heating\ or\ cooling}}$
- Biomass fuels used to produce electricity, heating and/or cooling
  - Threshold: at least 80 % reduction
  - Comparators: 183 $gCO_2eq./MJ_{\mathbf{electricity}}$ and 80 $gCO_2eq./MJ_{\mathbf{heating\ or\ cooling}}$

RED (Annexes V and VI) includes a large number of default values for each step in the value chains, depending on feedstock cultivation, process, transportation, etc. The company responsible for compliance can choose to use the default values or calculate actual values for its specific value chain. If actual values are used, these need to be verified which is normally done by certification under one of the approved certification schemes (see below). As described above, the principles for calculation of actual values are laid out in the RED. The default values are based on the same principles, but uses consistently "conservative" assumptions, meaning that the resulting emissions in most cases are significantly higher than the actual values of a producer's specific value chain. As a result, many producers choose to go through the extra administrative costs associated with calculating actual values.

6.3 Sustainability criteria in voluntary schemes and standards

6.3.1 Voluntary schemes approved under the RED

The European Commission has identified in total 18 voluntary and national certification schemes that are officially recognized for certifying the compliance with the sustainability criteria included in the RED. The certification schemes are mostly developed by independent multi-stakeholder organisations.

[64] For sake of brevity, the list has been limited to include only the highest applicable threshold for each fuel type or application. In general, lower thresholds apply during a transitional period. For all applicable thresholds, see article 29.10.

As such, the schemes check that

- production of feedstock used for the production of biofuels, bioliquids and biomass fuels does not violate the land use related sustainability criteria of RED;
- electricity used for the production of renewable hydrogen is of renewable origin;
- production of renewable fuels and gases leads to sufficient greenhouse gas emissions savings, according to the RED thresholds.

Note, that although further aspects are not included in the RED sustainability criteria, several schemes also consider other sustainability aspects such as emissions to soil, water and air, and social criteria. Biofuel production certified according to these schemes are thus certified to comply also with these criteria, specified by the certification schemes.[65]

6.3.2 Voluntary schemes for certification of feedstock

Some of the organisations behind the voluntary certification schemes referred to above, also offer versions of the schemes that are directed towards sustainability certification of feedstock for markets that are not regulated by RED. There are primarily three schemes for chain of custody certification that are developed to consider integrated production processes and therefore are used by the chemical industry.

These three schemes are the *International Sustainability and Carbon Certification PLUS* (ISCC PLUS)[66], the REDcert2[67] and the *Roundtable of Sustainable Biomaterials Standard for Advanced Products (RSB AP)*[68]. These schemes are based on the corresponding "RED compliant" scheme (ISCC EU, REDcert-EUand RSB EU RED, respectively) and include thus in principle the same land use related sustainability criteria (and the same additional sustainability criteria) as these. All three are also used to certify both biobased and recycled feedstock. Further, they include principles for how to take the sourcing of biobased material into account when calculating GHG emissions' savings. However, according to both ISCC PLUS and REDcert2, calculation and reporting of GHG emissions' savings are

[65] European Commission (n.d.). *Voluntary schemes.* https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/voluntary-schemes_en (Accessed 2025-09-01)

[66] ISCC International Sustainability & Carbon Certification (n.d.). *ISCC Plus.* https://www.iscc-system.org/certification/iscc-certification-schemes/iscc-plus/ (Accessed 2025-09-01)

[67] REDcert (n.d.). *REDcert Your parnter for sustainability certification*. https://www.redcert.org/en-us/?tx_news_pi1%5Baction%5D=detail&tx_news_pi1%5Bcontroller%5D=News&cHash=7bb3e6644adfe0c75be95648f4899b5e (Accessed 2025-09-01)

[68] RSB – Roundtable on Sustainable Biomaterials (2018). *RSB Standard for Advanced Products (Non-energy use)*. https://rsb.org/wp-content/uploads/2025/02/rsb-std-02-001-v2.0_rsb-standard-for-advanced-products.pdf. (Accessed 2025-09-01)

voluntary. Certification according to RSB AP requires at least 10% reduction compared to a fossil value chain.

All the schemes are thus based on a chain of custody principle, in which they allow for allocation of sustainability characteristics in the production process according to what is described as a mass balance approach. This means that certified (biobased or recycled) and non-certified materials can be physically mixed and converted in integrated processes, while the sustainability characteristics remain assigned to batches of material through verifiable bookkeeping. If certified feedstock has replaced an equivalent amount of fossil raw materials in a multi-output production process – and its quantity is monitored and documented – the certified shares can be allocated to certain outputs, ensuring the quantity of the certified feedstock accurately corresponds to the amount claimed in the finished good. Since the certified shares can be attributed to a specific product (following specific accounting principles), the amount of biobased content is not necessarily physically measurable (and cannot be claimed as "biobased content") in the specific certified product. The three systems mentioned above are similar in many respects, but there are also some differences in approach. These are further elaborated on in Nyström et al (2020).[69]

6.3.3 Standards

Standards are used to define technical or quality specifications with which current or future products, production processes or services may comply. Standards are to be used voluntarily but may be used as reference in regulations from authorities and in procurement. Many standards are used for certification, i.e. a procedure by which a third party gives written assurance that a product, process or service is in conformity with certain standards, but there are standards that are intended for other purposes, e.g. terminology and guidance.

International Trade Center (ITC), an agency of the United Nations, has developed the tool Standards Map[70], a database that presents information on 366 voluntary sustainability standards, applicable to sectors including agriculture, textile and garments, consumer products, forestry, mining, and services. The search for verification/certification systems in the database using "biomass" as search parameter gave no result. Filtering on the

[69] Nyström et al (2020) *Standards and certification schemes related to the mass balance approach – Applications in chemical industry*. CIT Industriell Energi. https://klimatledande.lindholmen.se/sites/default/files/2024-01/report_mass-balance_approved_200406_3.pdf f

[70] ITC Standards Map (n.d). *Standards Map free toolkit*. https://www.standardsmap.org/en/home. (Accessed 2025-09-01)

predefined “chemical sector”, which was considered as the most relevant sector for the scope of this project, resulted in a list of ten standards. None of these standards coincides with the certification schemes that comply with the EU RED III sustainability criteria for biofuels.

EN 16751 BIOBASED PRODUCTS – SUSTAINABILITY CRITERIA

EN 16751 Biobased products – Sustainability criteria[71] is a European standard developed on a mandate from the Commission as part of the Lead Market Initiative. The standard applies to all biobased products from all types of biomasses, except food, animal feed and biomass for energy purposes and covers all three pillars of sustainability (environmental, social, and economic). It defines principles, criteria, and indicators to provide information on how the economic operator is managing the identified sustainability aspects. The standard can be used as a tool for two areas of application: how to provide sustainability information regarding biomass production alone or how to provide sustainability information in the supply chain for the biobased part of a biobased product.

When *primary* feedstock is used, its origin (e.g. territorial unit) shall be documented. If it is obtained from land with high biodiversity value and/or land with high carbon stock the type shall be specified. For marine biomass the FAO Major Fishing Areas code shall be specified at subdivision level. When using *secondary* feedstock or waste the type shall be documented.

For all LCA- related topics, this standard (ISO 16751) refers to *EN 16760 Biobased products – Life Cycle Assessment*[72] (see 7.3). Together with Swedish stakeholders from forestry and industry, SIS Swedish Institute for Standards has published a guide to the standard[73] to be applied on raw material from Swedish forestry. SIS has shared a webinar about the standard and the guide[74].

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[71] Swedish standard · SS-EN 16751:2016. *Bio-based products - Sustainability criteria.* SIS Swedish Institute for Standards. https://www.sis.se/produkter/miljo-och-halsoskydd-sakerhet/miljoskydd/biobaserade-produkter/ssen167512016/

[72] Swedish standard · SS-EN 16750:2016. *Bio-based products – Life Cycle Assessment.* SIS Swedish Institute for Standards. https://www.sis.se/produkter/miljo-och-halsoskydd-sakerhet/miljoskydd/biobaserade-produkter/ssen167602015/

[73] Swedish Standards Institute (2020). *Hållbarhetsaspekter för svensk skogsråvara – Vägledning till SS-EN 16751:2016 Biobaserade produkter – Hållbarhetskriterier*. https://www.sis.se/bcker/hallbarhetsaspekter-for-svensk-skogsravara--vagledning-till-ss-en-167512016-biobaserade-/

[74] Bioinnovation (n.d.). *Om handboken ”Hållbarhetsaspekter för svensk skogsråvara – vägledning till SS-EN 16751:2016. ”* . https://www.youtube.com/watch?v=SQCmph4MPMg

UPCOMING RELEVANT STANDARDS WITHIN THE EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN)

CEN[75] is one of three[76] European Standardization Organizations that have been officially recognized by the EU and by the EFTA[77] as being responsible for developing and defining voluntary standards at European level.

The work programme within CEN/TC 411, the committee that is responsible for the development of standards for bio-based products covering so called horizontal aspects[78]; has several upcoming standards per today (October 2025), out of which sustainability criteria is one. However, it is not to be expected until April 2027. The committee is currently lead by SIS.

6.3.4 Product environmental labelling

Product environmental labels are usually categorized in three types [79]:

- Type I environmental labelling, for eco-labelling schemes where there are clearly defined criteria for products;
- Type II self-declared environmental claims, for products and services where there are neither criteria nor labelling schemes.
- Type III environmental declarations, for specific aspects of products using a life-cycle approach.

There are ISO standards that establish principles and provisions for labels of these types and what requirements that have to be met to be certified against them.

Below, we will give examples of environmental labelling type I and type III.

TYPE I: EU ECOLABEL

The EU Ecolabel is a voluntary scheme promoting goods and services that can demonstrate environmental excellence, based on standardised processes and scientific evidence. The framework for the scheme is set out in an

[75] CEN (n.d.). *About CEN.* https://www.cencenelec.eu/about-cen/

[76] The other two are CENELEC for electrotechnical standardization and ETSI for telecommunication standardisation.

[77] European Free Trade Association

[78] Consistent terminology, sampling, certification tools, bio-based content, application of and correlation towards life cycle analysis, sustainability criteria for biomass used and for final products, and aspects where further harmonization is needed on horizontal level. (https://standards.cencenelec.eu/dyn/www/f?p=205:7:0::::FSP_ORG_ID:874780&cs=18C173D69008BCCEB753FFD8DCAA03196)

[79] ISO environment (2019). *Environmental labels.* https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100323.pdf

official Regulation of the European Parliament and of the Council[80]. EU Ecolabel is the only EU-wide ISO 14024 Type I ecolabelling scheme, it is multi-criteria and tackles the main environmental impacts of products along their full lifecycle.[81]

EU Ecolabel criteria are established for different product groups and need to be met by the products to be awarded the label. Currently, there are EU Ecolabel criteria documents for eleven product groups, encompassing 25 product categories[82]. Without having checked all 25 documents (only the first criteria document in each group has been reviewed), it can be concluded that there is very limited use of criteria based on BBP; only the *Commission Decision (EU) 2023/1809 of 14 September 2023*[83] establishing the EU Ecolabel criteria for absorbent hygiene products and for reusable menstrual cups include such a criterion. It is a voluntary criterion and applies to the final product, separate components, and/or packaging that contain > 1% w/w of biobased plastic material. The applicant of the EU Ecolabel may source a certain percentage of the total synthetic polymers and plastic materials (in relation to the total weight of polymers in the final product[84], the separate components and/or in the packaging) from biobased raw materials. Circular economy principles (e.g. prioritising the use of organic waste and by-products as feedstock in line with the *EU Policy Framework on biobased, biodegradable, and compostable plastics*[85]) shall guide the selection of feedstocks. In this case, the applicant of the EU Ecolabel must make sure that two requirements are fulfilled:

(a) The superior environmental profile of the biobased raw materials used to produce BBP in the final product, separate components, and/or packaging shall be demonstrated. The impacts of BBP compared to fossil-based plastics shall be assessed in compliance with the latest applicable

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[80] Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010R0066

[81] European Commission (n.d.) *About the EU Ecolabel.* https://environment.ec.europa.eu/topics/circular-economy/eu-ecolabel/about-eu-ecolabel_en

[82] European Commission (n.d.) *Product Groups and Criteria.* https://environment.ec.europa.eu/topics/circular-economy/eu-ecolabel/product-groups-and-criteria_en#criteria

[83] Commission Decision (EU) 2023/1809 of 14 September 2023 establishing the EU Ecolabel criteria for absorbent hygiene products and for reusable menstrual cups (notified under document C(2023) 6024). https://eur-lex.europa.eu/eli/dec/2023/1809/oj/eng

[84] Including super absorbent polymers (SAP)

[85] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. EU policy framework on biobased, biodegradable and compostable plastics. https://environment.ec.europa.eu/publications/communication-eu-policy-framework-biobased-biodegradable-and-compostable-plastics_en

methodologies, currently the "Plastics LCA method"[86] or the "Safe and sustainable by design" chemicals and materials[87]. The applicant shall provide an independent third-party certification that refers to the methodology currently available.

(b) Biobased raw materials used to produce BBP in the final product, separate components, and/or packaging shall be covered by chain of custody certificates. These certificates shall be valid for the whole duration of the EU Ecolabel licence and checked every 12 months after the awarding of the EU. They must be issued by an independent third-party certification scheme officially recognised by the European Commission, in line with the sustainability requirements related to the sourcing of biobased raw material as per the review of the Renewable Energy Directive (RED III) (see 6.2)

The final product, separate components, and/or packaging may be voluntarily labelled as containing biobased plastic. In this case, the claim must follow a stipulated wording. Generic claims such as 'bioplastics', 'biobased', 'plant-based', 'natural-based' and similar shall not be used. The biobased carbon content shall be determined using standards based on radiocarbon methods. When radiocarbon methods cannot be used, the mass balance method is allowed if a high level of transparency and accountability is ensured and supported by agreed standards. The use of purchased certificates based on the Book & Claim system is excluded to enable traceability of the biobased plastic raw materials. The fact that the criterion is voluntary, accompanied with demanding requirements on verification of the environmental profile of the biobased content and none on the conventional one, is most likely prohibitive for the adoption of it. The Nordic Swan Ecolabel is an ISO 14024 Type I ecolabelling scheme certifying that a product or service complies with the requirements of the label. In general, the Nordic Swan Ecolabel requirements promote the use of biobased raw materials over virgin fossil-based, if this does not create new

[86] Nessi, S., Sinkko, T., Bulgheroni, C., Garcia-Gutierrez, P., Giuntoli, J., Konti, A., Sanye Mengual, E., Tonini, D., Pant, R., Marelli, L. and Ardente, F., *Life Cycle Assessment (LCA) of alternative feedstocks for plastics production*, EUR 30725 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-38145-7, doi:10.2760/271095, JRC125046. https://publications.jrc.ec.europa.eu/repository/handle/JRC125046

[87] COMMISSION RECOMMENDATION Commission recommendation of 8.12.2022 establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials. https://research-and-innovation.ec.europa.eu/system/files/2022-12/Commission%20recommendation%20-%20establishing%20a%20European%20assessment%20framework%20for%20safe%20and%20sustainable%20by%20design.PDF

environmental problems. Requirements for the Nordic Swan Ecolabel for BBP feedstock include[88]:

- Primary raw materials: a certification according to credible third-party standards and certification schemes that follow certain principles.
- Secondary raw materials: waste or residual products defined in line with (EU) Renewable Energy Directive 2018/2001. Traceability to the formation of the secondary raw material must be ensured.
- Recycled raw materials: documentation (following the standard for self-declared environmental labels and claims ISO 14021) to prove that the material is recycled.

TYPE III: THE INTERNATIONAL EPD SYSTEM

An environmental product declaration (EPD) provides third-party verified information about the environmental performance of a product or service throughout its life cycle. An EPD is based on a life cycle assessment (LCA) methodology according to ISO 14040 and 14044, conducted in accordance with Product Category Rules (PCRs). The International EPD System (IES) is one of the larger, globally recognized program operators for EPDs. The General Program Instructions (GPI) for IES forms the basis of the operation of the program and includes e.g. general provisions for the development of PCRs.

According to the GPI, the current position of the International EPD System is that mass balancing does not follow EN 15804 and related standards and shall not be used in EPDs; claims on the reductions of GHG emissions, or reporting of certificates, based on a mass balance approach are not allowed. These rules concern not only the content of the declared product, but also the content of materials and products used in the product system. Biogas supplied through grids and used for energy purposes in the product system are exempted from these rules.[89]

[88] Nordic Swan (n.d.) *Bio-based plastics.* https://www.nordic-swan-ecolabel.org/nordic-ecolabelling/environmental-aspects/circular-economy-and-resource-efficiency/biobased-plastics/ (Accessed 2025-09-01)

[89] International EPED System (2025). *General Programme Instructions for the International EPD System.* Version 5.0.1. https://www.datocms-assets.com/37502/1744981993-gpi5-0-1_20250227.pdf

7. Sustainability criteria for biobased plastics

In this chapter, options for introducing sustainability criteria for production of BBP are discussed and analysed, based on the overview of current use of sustainability criteria in Chapter 6, and stakeholder input from literature and interviews (summarized in Chapter 5).

7.1 Principle considerations and summary of analysis

The overview above shows that there are a broad range of sustainability criteria in use, that may be valuable for ensuring minimum impact on sustainability from BBP. This means, that in principle sustainability criteria for biobased plastic can be designed at different levels, from a minimal level to the full range of criteria mentioned in Section 6.1. Here we have chosen to focus the discussion on criteria related to the following three groups of aspects:

- Land use and land use change related sustainability criteria
- GHG emissions criteria
- Other key criteria not included in the RED III

More detail on land use related and GHG criteria, can be found in Sections 8.2 and 8.3, respectively. The overall implications and conclusions from the analysis are summarized below and then discussed in more detail in Section 7.4. At a general level, we find that the extensive development process and widespread adoption of the RED III sustainability criteria make them a good starting point for sustainability criteria also for bioplastics. As described above the RED III criteria are not only used by that directive but also included in a range of other EU regulatory frameworks. Levelling the playing field between different uses of biomass is also, in general, strongly advocated by the stakeholders.

Until now, regulated criteria have only been applied for biomass used for biofuels and not for products, which altogether risk contributing to biased market effects. A situation with stricter sustainability criteria for BBP than for biofuels would lead to similar, but reversed, effects.

In fact, it was stated already in the preconditions of this study that sustainability criteria for bioplastics should not be stricter or more encompassing than those of biofuels. Furthermore, practical aspects need to

be taken into account and an alignment of sustainability criteria for plastics with the existing RED-criteria would facilitate the implementation. Thus, there are several arguments in favour for aligning sustainability criteria, to the extent possible, with the RED III.

This is also in line with the recommendations of the Trinomics study[90], where the authors recommended to align with the sustainability criteria and with the assessment methods that apply to the energy sector as specified in RED (at the time of publishing, RED II). In addition, they considered that the requirements could in time become more stringent for both bioenergy and BBP, to reduce the risks of unsustainable production of biomass and to maintain a level playing field for different applications of biomass. Furthermore, the authors stressed the importance of optimizing the contribution from BBP to circular economy, an additional consideration not applicable for bioenergy.

However, due to differences in production processes, the broad array of plastic products (compared with the rather small number of commercially relevant fossil fuels) and the product life cycle of plastics, it is not possible to simply transfer the criteria in all aspects. More specifically, the GHG emission savings requirements from REDIII (and the methodology for their calculation) cannot be applied to biobased polymers and plastics without methodological adjustments. For the development of methodology and criteria, also other methodologies - developed in LCA-related standards and those applied in already existing certification schemes for biobased products - need to be taken into account. Therefore, the different principles, in relation to BBP, are further described in Section 7.3.

In Table 2 the approach taken towards the three groups of criteria, above, are summarized. The implications for development of GHG criteria are further discussed in Section 7.4.

Table 2 Summary of approach and relevant issues, in relation to the three groups of criteria.

Type of criteria	Summary	Further comments
Land use related criteria	Land use related criteria can and should be directly based on the criteria used in RED III. The feedstocks used for production of plastics has a complete overlap with	The RED III land use related criteria would reflect a minimum level of sustainability criteria for BBP.

[90] European Commission: Directorate-General for Environment, Trinomics, Wageningen and Wood (2022). *Biobased plastic – Sustainable sourcing and content – Final report*, Publications Office of the European Union. https://data.europa.eu/doi/10.2779/668096

	those used for biofuels and we have found no strong arguments for why they should differ. These aspects can also be considered well covered by the RED III criteria.	
GHG criteria	Inclusion of GHG criteria is necessary to safeguard against the use of bio feedstock and production processes with high carbon footprint. The GHG criteria used for biofuels cannot be directly transferred to the plastics industry. Choices are needed for: - Product granularity and value chain position - Product specific fossil comparators - Required savings relative to fossil comparators - Principles for allocation of emissions in co-processing (valid for chemical industries) - Handling of end-of-life emissions (relevant for plastics). - Actual vs default values	Can, in principle, be excluded if related policy measures focus on shares/amounts of BBP. Product level and comparators must mirror the large number of plastic value chains. At the same time, the number of comparators should be limited. Methodologies differ in principles for "allocation" of emissions for co-processing – from requiring physical content to allowing (different levels of) mass balancing. End-of life emissions (for fossil comparator) depend widely on type of plastic products (their lifetime and recycling rates). Default values increase costs for regulatory body, actual values put costs on market actors.
Criteria related to other key aspects	In RED III, criteria related specifically to biodiversity, resource efficiency, other emissions to air, water and soil or social responsibility criteria are not included. They are in general included in the criteria applied by certification schemes recognized by	Possibly, these criteria could gradually be further developed, then applicable to biomass used for both energy and as feedstock for plastics.

	the EU and those mostly applied for certification of products (like RSB AP and ISCC PLUS). Some of the aspects are also handled through other regulatory systems (not in focus here). Energy efficiency is indirectly taken into account by RED III, through the GHG criteria. These criteria could be treated in the same way for BBP as for biofuels.	

7.2 Land use related criteria

With sustainability criteria we here mean correspond to the sustainability criteria for biofuel in RED III, as stipulated by article 29.2-7 of the directive (see Section 6.2.2). These are all directly related to land use or management and concern only the biomass feedstock.

Those criteria are the result of extensive negotiations between the member states and are already used in several legal acts besides RED III, and in voluntary certification schemes. Since we have concluded that there is no need to require different levels of sustainability for biomass depending on its use case, the feedstock biomass criteria for feedstock intended for BBP can be the same.

7.3 Criteria for GHG emission savings

7.3.1 Fossil comparators and required savings

The RED III GHG emissions saving criteria for biofuels (article 29.10) are tailored to specific biofuel applications using fossil fuel reference values ("comparators"), against which GHG emission savings are determined. The comparators are default emission intensities for a fossil fuel performing a specific function (e.g., 94 g CO_2eq./MJ_{fuel} for motor fuels or 183 g CO_2eq./$MJ_{electricity}$ for electricity produced from fossil fuels) and account for emissions arising over the entire life cycle of the fuel. Each biofuel must achieve a specific level of savings (%) compared to the comparator. Similarly, each plastic would have to achieve a specific level of savings (%) compared to its fossil equivalent.

If the biofuel GHG criteria were applied to biopolymers and bioplastics, they would have the following forms:

*"The greenhouse gas emission savings from the use of bioplastics shall be at least **X** % , measured over the entire life cycle and in relation to a fossil comparator. The fossil comparator shall be **Y** gCO2eq./g plastic"*

Consequently, an adoption of RED-inspired GHG criteria for bioplastics requires: 1) the definition of suitable fossil comparators and reasonable levels of emissions savings (accounting for relevant climate targets and what is achievable using available technology), and 2) a methodology to calculate the emission savings from the use of bioplastics. These aspects are discussed below, with the existing RED methodology as a starting point.

A vast array of different (fossil) plastics – with very different GHG emissions intensities – are in use today. Therefore, it will not be sufficient to define one single fossil comparator applicable to all plastics. Therefore, two options have been identified. One extreme is to define individual fossil comparators for each type of plastic or plastic product that is covered by the criteria – a daunting task considering the many types of plastics. The other solution is to define fossil comparators for a smaller number of "platform" or "intermediate" polymers or plastics that are used to produce most plastics. The two options for the fossil comparators are illustrated in Figure 8.Figure 8

If an intermediate platform polymer or plastic is used as the point of comparison between fossil and bio-based value chains, any differences that occur downstream of the intermediate will not be captured by the comparison. Consequently, the intermediate polymer/plastic should ideally be chosen so that the downstream value chain can be assumed to be identical. This is straightforward if a chemically identical platform molecule (e.g., (poly-)ethylene) can be produced from either fossil or bio-based feedstock, i.e., for drop-in plastics.

For substitution plastics (see 2.2) – where there is no direct fossil equivalent – the emission savings need instead be evaluated against the fossil comparator (for a platform or a final plastic, depending on the chosen approach) corresponding to the fossil plastic that the substitution bioplastic replaces. Here, an evaluation will be needed based on the most common usage areas of the substitution plastics and replacements, since the plastics will not be perfect substitutes and replacements will depend on the final products. For substitution plastics, the value chain downstream of the platform will not be entirely identical. To guarantee that the use of substitution plastics achieves emission reductions, a case-by-case assessment is needed to make sure that any differences in emissions

downstream of the platform are negligible in comparison to the emissions evaluated at the platform level.

Note that – even if bio- and fossil value chains are identical downstream of the platform – the fact that the carbon content is of different origin (fossil or biobased) will lead to a significant difference in total emissions (see the discussion on GHG calculations below).

Regardless of how the comparators are chosen, the required savings in relation to the comparators must be selected considering the available pathways for biobased production and relevant climate targets. The selected savings threshold(s) will also depend on the scope of the calculation methodology and – in particular – its treatment of end-of-life emissions (see the discussion on GHG calculations below).

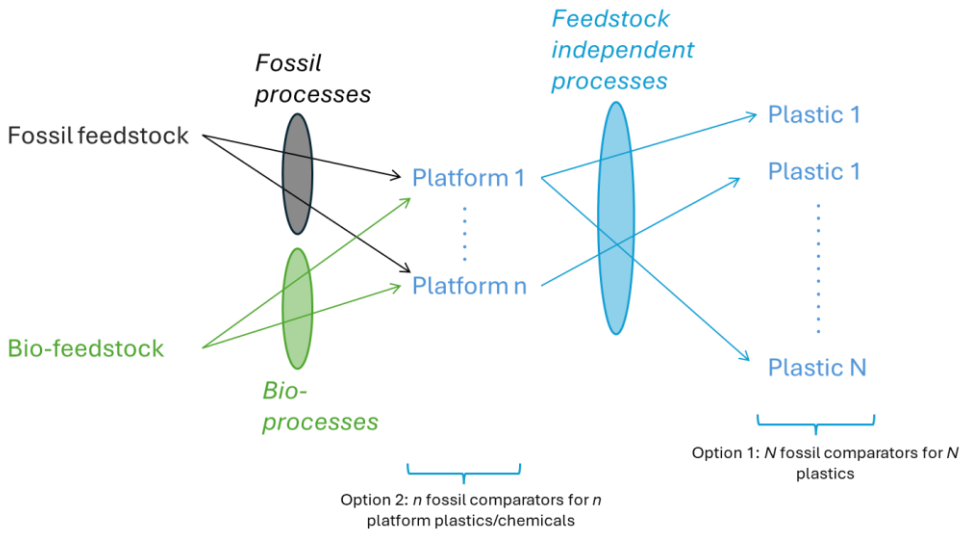

Figure 8 Principal illustration of different options for product granularity and choice of fossil comparators.

To limit the number of fossil comparators and achieve a more streamlined regulation, our preferred approach is to define comparators at a "platform" level, and we have used this as the main case in the following sections.

7.3.2 REDIII GHG Calculation methodology applied to biobased plastics

The GHG calculation methodology of RED III is "technology neutral" meaning that it doesn't give any calculation rules that are specific to certain technologies or pathways for biofuel production. Instead, the methodology describes a generalized production pathway from biomass cultivation and harvesting to biofuel production and use. The generic nature of the

methodology means that it can be adopted for bioplastic value chains without major changes.

A detailed interpretation of each of the variables of the GHG calculation equation described in Section 6.2.3, for the case of production of poly-ethene from bioethanol can be found in Appendix 4. The example is thus developed for the case where the GHG criteria relates to an intermediate product (poly-ethene) and includes an approach to handling the end-use phase.

Overall, it should be noted that emissions arising in each step of the value chain are forwarded to the next step and that, every time a co-product is generated, upstream emissions are allocated between the main product and the co-product. Although the calculation methodology (and equation) is simple in principle, large amounts of verified data will be needed for long value chains with multiple processing steps. The required data include e.g., process yields and energy demand for each processing step, the amounts of co-product(s) generated in each step, and fuel consumption for transport of feedstock, intermediates, and final products.

The specific parts of the methodology that require special considerations for BBP are discussed in further detail below.

Firstly, it should be noted that – if emissions for BBP and the fossil comparator are assessed at an intermediate point in the value chain – some processing steps (and their corresponding emissions) are left out of the calculation. If the processing steps that are left out are identical for BBP and fossil plastics the calculated emissions for the intermediate product can still be useful to compare the value chains – but one should be aware that the absolute values do not correspond to the entire value chain.

Secondly, the RED methodology ends with the fuel's use-phase and doesn't include an end-of-life phase. This is because the end-of-life phase of a fuel coincides with its use-phase (i.e., the combustion of the fuel). For plastics, use-phase emissions are essentially zero (or, rather: there is no difference between fossil and biobased alternatives), but several end-of-life options exist (e.g., incineration or recycling) and emissions can be significant. To simplify the calculation of end-of-life emissions, it would make sense to only include differences between the fossil plastic and its bio-based counterpart. For substitution plastics, any differences in processing emissions during end-of-life must also be accounted for.

If incineration is the likely fate of the plastic, CO_2 emissions corresponding to stoichiometric combustion of the carbon content of the plastic enter the atmosphere during end-of-life (for a calculation made at the "intermediate level" the emissions should be based on the carbon content of the

intermediate product). This CO_2 is zero-rated for BBP and will cause a substantial difference compared to the fossil reference.

If a plastic is fully recycled or used for very long-life products, the carbon content may be considered "permanently" stored. In this case, there will be zero end-of-life emissions due to the carbon content of the fossil polymer/plastic. The bio-option, which is linked to a biogenic carbon uptake at the beginning of the value chain, would infer a CO_2 removal ("negative emission") corresponding to stoichiometric combustion of the carbon content.

Consequently, no matter if the plastic is incinerated, recycled or used in long-life products, a difference in emissions equal to the stoichiometric combustion of the plastic/polymer carbon content will occur between the fossil and bio-based value chain during end-of-life, given that their end-of-life treatment is identical. However, if the BBP have a different fate than the fossil counterpart (e.g., is recycled at a higher rate the difference can be higher or lower than the stoichiometric CO_2-content).

In reality, a mix of end-of-life treatments are used, and this should be reflected in the methodology. The fossil comparators should therefore, if possible, be calculated using the actual mix of end-of-life treatments used in the representative market (e.g. EU or Sweden) for that specific plastic. This mix should be the default option for the bio-based emission calculation as well, but a producer should be able to use a different mix of end-of-life *if* it can prove that said mix is applicable to its products.

Thirdly, the methodology generally uses energy allocation to distribute emissions between main and co-products arising along the value chain. This allocation principle is easy to use in practice and to align with the RED methodology it would make sense to use energy allocation for plastics as well. However, for non-energetic products (such as plastics) mass allocation may be more suitable. This allocation principle is equally simple to use and is allowed under, e.g., ISCC PLUS.

More important and challenging than the base (energy or mass) used for allocation are the allocation principles applied for co-processing. It is likely that many producers of bioplastics will co-process biogenic and fossil feedstocks in plants that produce many products. The GHG methodology must have rules to determine the biogenic content of each product produced in such a plant, and rules to determine the emission intensity of the biogenic fraction of each product. There are such rules associated with the RED III

methodology[91], but there may be practical challenges with adapting them to plastic production processes which are often more complex than refinery processes, in terms of the number of interconnected process steps, co-products and process streams (see also Section 7.4.1).

7.3.3 GHG emission calculation in standards for LCA

There are also standards for life cycle analysis, that include provisions for calculation of GHG emissions. The general approaches of the most important standards are summarized below.

EN 16760:2015 BIOBASED PRODUCTS – LIFE CYCLE ASSESSMENT

EN 16760 Biobased products – Life Cycle Assessment[92] provides specific life cycle assessment (LCA) requirements and guidance to assess the impact over the life cycle of biobased products with the focus on how to handle the specificities of the biobased part of a product, excluding food, feed, and energy. It is based on EN ISO 14040[93] and EN ISO 14044[94]. For studies aiming at a comparative assertion intended to be disclosed to the public, a life cycle impact assessment shall be performed and a critical review is needed. Furthermore, additional requirements as set in EN ISO 14044:2006 apply for this kind of studies.

EN 18027:2025 BIO-BASED PRODUCTS — LIFE CYCLE ASSESSMENT — ADDITIONAL REQUIREMENTS AND GUIDELINES FOR COMPARING THE LIFE CYCLES OF BIO-BASED PRODUCTS WITH THEIR FOSSIL-BASED EQUIVALENTS

This standard[95] was published in April 2025 and provides requirements and guidelines for comparing the life cycles of bio-based products with their fossil-based equivalents (here "equivalents" generally refers to the "functional equivalence"). The standard builds on existing LCA

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[91] The rules to determine the share of biofuel produced by a co-processing plants are not established in the GHG methodology but in Commission Delegated Regulation (EU) 2023/1640 of 5 June 2023 on the methodology to determine the share of biofuel and biogas for transport, produced from biomass being processed with fossil fuels in a common process. https://eur-lex.europa.eu/eli/reg_del/2023/1640/oj/eng

[92] Swedish standard SS-EN 16760:2015. *Bio-based products - Sustainability criteria.* SIS Swedish Institute for Standards. https://www.sis.se/produkter/miljo-och-halsoskydd-sakerhet/miljoskydd/biobaserade-produkter/ssen167602015/

[93] ISO 14040:2006. *Environmental management - Life cycle assessment - Principles and framework*. https://www.iso.org/standard/37456.html

[94] ISO 14044:2006. *Environmental management - Life cycle assessment - Requirements and guidelines* https://www.iso.org/standard/38498.html

[95] Swedish Standard SS-EN 18027:2025. *Bio-based products — Life cycle assessment — Additional requirements and guidelines for comparing the life cycles of bio-based products with their fossil-based equivalents.* https://www.sis.se/produkter/miljo-och-halsoskydd-sakerhet/miljoskydd/produkters-livscykler/ss-en-180272025/

methodology and gives additional provisions for modelling carbon flows and impact assessment of these with respect to time perspective. Greenhouse gas (GHG) emissions and removals arising from fossil carbon sources and biogenic carbon sources and sinks shall be included and listed separately in the inventory, which shall cover all carbon flows in such a way that the effect of choices related to stored or released carbon (biogenic or fossil, respectively) and storage period(s) at the product end-of-life can be assessed in sensitivity analyses. Following EN ISO 14044, multi-functionality shall be handled, if possible, by subdivision or by system expansion to avoid allocation. The following paragraph implies that the standard does allow mass balancing:

> *Biogenic and fossil carbon content and flows shall be allocated reflecting the physical flows according to stoichiometric rules irrespective of the allocation chosen for the process. Alternative allocation approaches can lead to the modelled biogenic and fossil carbon flows not reflecting the actual physical content.*

For cradle to gate studies, biogenic or fossil carbon content in the products shall be reported separately to allow to calculate carbon emissions in end-of-life. Regarding end-of-life, the assessment should include clearly stated assumptions concerning the distribution of the waste stream between the end-of-life options (either ideal, optimum situation, or the current situation), and ideally should test the sensitivity of results to variations in this distribution. The standard includes the same provisions for comparative assertion studies as ISO16760 and ISO14044. In an informative annex, the standard provides an overview of key aspects of approaches for biogenic carbon accounting adopted in relevant standards and guidelines.

Essity, Perstorp och TetraPak were some of the Swedish organisations that were active in the development, led by SIS[96].

7.3.4 Other relevant GHG emission calculation methodologies

Standards as those mentioned above are important and can be useful for LCAs for “inhouse” applications, so called hot spot analysis and identification of potential improvements of the environmental performance of products and services. However - and this is both their weakness and their strength - they are often open to interpretations by the LCA

[96] SIS (2023). *Rättvisa jämförelser av bio- och fossilbaserade produkters klimatpåverkan.* https://www.sis.se/nyheter-och-press/nyheter/rattvisa-jamforelser-av-bio--och-fossilbaserade-produkters-klimatpaverkan/ (Accessed 2025-09-01)

practitioners. This make them less robust for other purposes such as comparative assertion[97] and consumer communication; they do allow comparative assertions and communication to the public, but LCA calculations have in many cases, both rightly and wrongly, been accused of providing evidence for whatever interest the LCA commissioner or practitioner may have, especially for communication purposes.

To address these (alleged or actual) flaws, not least expressed by industry itself, but also for other reasons, and to tidy up in the plethora of environmental labels that were jeopardising the power of the consumers to make informed choices based on solid facts, the European Council invited the European Commission in 2008 to develop a methodology for product environmental footprints [98]. To begin with the scope was carbon footprint, but soon it became clear that, for many product groups, there were other equally important impact categories. Hence, the scope was widened in 2011. The Product Environmental Footprint (PEF) method was presented in 2013 and updated in 2021. [99, 100] PEF provide harmonised rules for assessment of the environmental impacts of products throughout the life cycle.

To complement PEF, the Joint Research Centre (JRC) has elaborated the Plastics LCA method[101] (below P-LCA-method) to evaluate the potential environmental impacts of plastic products from different feedstocks. Ensuring full consistency between the P-LCA and the PEF methods was an overarching aim for the development, but other relevant life cycle-based methods and approaches set out in the existing EU legislation were considered, as well as relevant international and European standards. The method was tested and illustrated in several case studies, reported in a separate supporting document[102]. In Appendix 5 below, some of the

[97] Comparative assertion is an environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function.

[98] A method was also developed for organisational environmental footprint, but in the context of this study, the interest lies only with the product-based method.

[99] European Commission (n.d.) *About the Environmental Footprint Methods.* https://green-forum.ec.europa.eu/green-business/environmental-footprint-methods/about-environmental-footprint-methods_en (Accessed 2025-09-15)

[100] Commission recommendations (EU) 2021/2279 of 15 December 2021 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021H2279

[101] Nessi, S., Sinkko, T., Bulgheroni, C., Garcia-Gutierrez, P., Giuntoli, J., Konti, A., Sanye Mengual, E., Tonini, D., Pant, R., Marelli, L. and Ardente, F., Life Cycle Assessment (LCA) of alternative feedstocks for plastics production, EUR 30725 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-38145-7, doi:10.2760/271095, JRC125046. https://publications.jrc.ec.europa.eu/repository/handle/JRC125046

[102] Nessi, S., Sinkko, T., Bulgheroni, C., Garbarino, E., Garcia-Gutierrez, P., Giuntoli, J., Konti, A., Orveillon, G., Sanye Mengual, E., Tonini, D., Pant, R., Marelli, L. and Ardente, F., Life Cycle

methodological issues that are relevant for polymers and plastics, both fossil and biobased, addressed in the P-LCA method, are described.

To be used for comparisons and comparative assertions, the PEF study shall be conducted in compliance with product environmental footprint category rules (PEFCR). The scope of a PEFCR can be an intermediate product, a final product or a group of subproducts. PEFCRs include provisions for which impact categories to be included in the PEF study. The impact category Climate change is mandatory in all PEFCRs, but what other impact categories to include are based on findings from the supporting studies that are carried out within the PEFCR development. A conclusion from these requirements is that "single issue" comparisons and comparative assertions, such as claims on GHG emission savings from biobased polymers and plastics, is not compliant with the PEF and P-LCA framework. However, that does not exclude using the calculation methodology itself for GHG emission reduction calculations, although the comparison or comparative assertion cannot be claimed as PEF compliant.

7.3.5 Chain of custody in LCA

In contrast to REDIII, common LCA practice does not allow for chain of custody modelling, that includes a separation of physical and accounted products. A recent paper[103] studied chain of custody modelling in carbon footprinting and life cycle assessment. The authors state that neither the ISO standards for LCA and GHG accounting, nor the GHG Protocol and Product Environmental Footprint, explicitly mention the term chain of custody or the corresponding models. Furthermore, they conclude that currently there seem to be no scientific literature that addresses chain of custody modelling in carbon footprinting and LCA on an overarching level - further research and specification are necessary to harmonize the standards for Chain of custody modelling and LCA. However, a new standard, ISO14077, is currently under development that aims to provide requirements and guidelines for the application of chain of custody models in LCA[104]. The Swedish Life Cycle Center[105] is currently running the project Consistent Standards for Life

Assessment (LCA) of alternative feedstocks for plastics production, EUR 31085 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-52958-3, doi:10.2760/655230, JRC127175. https://publications.jrc.ec.europa.eu/repository/handle/JRC127175

[103] Holzapfel, P., Blizniukova, D., Bach, V., Finkbeiner, M. (2025). *Chain of custody modelling in carbon footprinting and life cycle assessment.* The International Journal of Life Cycle Assessment (2025) 30:980–993, https://doi.org/10.1007/s11367-025-02452-9

[104] ISO/WD 14077.2. Environmental management — Life cycle assessment — Requirements and guidelines for application of Chain of Custody (CoC) approaches in Life Cycle Assessment (LCA) https://www.iso.org/standard/61120.html

[105] Member organisations from industry and authorities: see https://www.lifecyclecenter.se/about-us/

Cycle Assessment, funded by Net Zero Industry, a joint initiative by Vinnova, Formas and the Swedish Energy Agency. The project has actively contributed to e.g. the development of ISO 14077[106].

7.4 Implementation of sustainability criteria for biobased plastics

Based on the overview above, implications for implementation of criteria for BBP are further discussed below. Section 7.4.1 focuses on implementation of GHG emissions criteria for the approach of including criteria at the level of intermediate polymers or plastics, while alternative options for regulatory implementation are summarized in Section 7.4.2. No deeper investigation of the legal conditions related to the various options has been carried out.

7.4.1 Summary and discussion on technical aspects of implementation

Above (see Section 7.1 and Table 2) sustainability criteria for BBP were categorized into three groups: land use related criteria; GHG emissions criteria; and "other" criteria. For the first and last this study result in a clear conclusion that the preferred strategy is to fully align them with the RED III approach of inclusion and non-inclusion, respectively. Further, land use related criteria should in principle be the same for all types of BBP, regardless of the type of plastic products or end-use, since they are developed to protect certain land types, biodiversity etc. However, corresponding criteria are not in place for fossil fuels, and if there are no policy measures targeting the plastic in question the criteria would both be difficult to impose, and risk being sub-optimal. Additional, general implications related to the implementation of that are discussed in Section 7.4.2.

The third - the inclusion, design and implementation of GHG emission criteria for biobased plastic – is more complex. Therefore, the implementation of such criteria is further explored in this section, taking, as a starting point, the option of specifying the criteria for a limited number of intermediate polymers or plastics. (Other options are discussed at a more general level in Section 7.4.3).

[106] Swedish Life Cycle Center (2025). *Progress toward more consistent LCA standards.* https://www.lifecyclecenter.se/news/progress-toward-more-consistent-lca-standards/

To implement GHG criteria, detailed provisions for how to calculate the emissions for both fossil comparators and BBP need to be developed. To imply any certainty of the GHG emissions accounted for, such provisions will by necessity include requirements of a chain of custody (CoC) principle, in which data from one step in the value chain to the next (and from one operator to the next) are secured.

Further, input from stakeholder interviews and other industry indicate that for the industry to be able to take steps towards more biobased raw material, from the very low shares that are now used, the CoC used should allow for co-processing and some kind of mass balancing principle when allocating emissions to different products. With gradually increasing shares of biobased (and recycled) material this principle may be possible to review at a later stage.

The calculation methodologies reviewed above, that are based on LCA standards and frameworks (such as PEF and the Plastics LCA method) do currently not include any methods for mass balancing of raw material with different sustainability properties.

Consequently, the most practical approach seems to be to align the development of GHG emission criteria for BBP as closely as possible to the provisions and principles used by the RED III. The co-processing rules associated with the RED III methodology[107] are adapted for the production of biofuels in refineries. The plastic production processes are often more complex, in terms of the number of interconnected process steps, co-products and process streams. However, the rules could be based on as similar principles as possible.

The RED III rules for co-processing allows for mass-balancing over a certain period of time, and for allocating the biobased fuel to different markets (different blending levels). Which means that the measured biobased content does not (always) coincide with that specified for a certain product. The provisions do not, however, allow free attribution between products. This means that total biobased production should be allocated proportionately between all products of a refinery (including e.g. naphtha). This principle should be possible to implement also for production of

[107] The rules to determine the share of biofuel produced by a co-processing plants are not established in the GHG methodology but in in Commission Delegated Regulation (EU) 2023/1640 of 5 June 2023 on the methodology to determine the share of biofuel and biogas for transport, produced from biomass being processed with fossil fuels in a common process. https://eur-lex.europa.eu/eli/reg_del/2023/1640/oj/eng. The detailed implications of these provisions require some effort to interpret. The statement is primarily based on previous information from operators of biofuel production facilities.

polymers and plastics, at least at the intermediate level that is discussed here.

Further, to avoid imposing too costly regulations on the industrial operators, a list of default values should be developed for the value chains included, following the same approach that has been used for the RED III.

According to this, economic operators should always be entitled to claim the level of greenhouse gas emissions savings for biobased platform chemicals and bio-polymers by that list. Operators who want to claim higher emission savings than the default value from a production pathway need to demonstrate this by providing actual values, calculated according to the same provisions. The RED III approach enables that these default values can be used modularly, so that emissions for different steps in the value chain can be combined and the values added together, resulting in total emissions. For the first steps in the value chain (e.g. cultivation of raw material, see also Appendix 4), the RED III default values can be used directly.

For the calculation of fossil GHG emission comparators also the emissions resulting from the end-of-life of the corresponding polymer or plastic need to be included. We propose that data is based on statistics for the country specific (e.g. Swedish) share of end-of-life treatments for the specific product group. Here, the choice of data should be made based on an estimation concerning the relation between the intermediate platform polymer or plastic and the most relevant product group(s). The choice can also be impacted by the targets of related policy measures (e.g. focusing on packaging).

The principle for calculating end-of-life emissions for BBP will be the same but released CO_2 will be zero-rated and carbon stored in long-lived or recycled products will be treated as negative emissions. If the end-of-life phase of the bio- and fossil value chains is identical the difference between them will equal the emissions from stoichiometric combustion of the carbon content. It is therefore possible to simplify this stage in the methodology by not considering the actual fate of the plastics, instead including a generic term equal to stoichiometric combustion (and zero-rate this for bio-based value chains). However, this simplification means that bio-plastic producers will not get a credit if their products can be proven to be longer-lived or recycled at a higher rate than the fossil reference.

The considerations above are summarised in Table 3.

Table 3 Overview of technical aspects of implementation of GHG emission criteria for BBP.

Choices needed	Approach in focus	Comments
Product level (and products)	GHG criteria set for a limited number of intermediate platform polymers/plastics. Takes complexity of plastic processing into account. (Challenging for substitution plastics.)	Implications from both "extremes" (raw material level and plastic product levels) discussed (from implementation perspective)
Determination of fossil comparators	For chosen intermediate platform polymers/plastics. Including end-of life emissions (see below)	
Principles for allocation for co-processing	Allocation based on energy (as in RED) or mass. Mass-balancing at the RED "level" (mixing and co-processing allowed as well as mass balancing over time; but not free attribution). May be challenging to develop clear "rules" for processing step in chemical industry (not analysed in detail in study).	Certification with existing schemes (for products) use less "strict" principles. LCA standards require measured content. ("Stricter" principle.)
Handling of end-of-life emissions	Include in development of GHG criteria, based on the country specific (e.g. Swedish) share of end-of-life treatments for specific plastics/product groups. Will impact level for fossil comparators (same principle for biomaterials, but emissions = 0).	Can include possibility to use proven "actual" values. Approach of climate bonus/malus (EUBP) relevant if end-of-life differ between bio and fossil plastic.
Actual vs default values	Use RED approach with modular default values that can be used. With option to use proven/certified actual values. RED data for value chain steps that coincide. Develop default values for plastic processing steps.	Default values need to be developed in dialogue with industry (need for data).

It should be noted that some of the allocation and calculation principles in the REDIII are still open for interpretation, which has been investigated in

detail in Petterson and Wickman (2025)[108]. According to this study, this includes some aspects that may be even more important when transferring the regulations from biofuel to BBP production (or for chemical products in general). The reason being the more complex co-processing value chains for BBP production. Examples include the possibility to be credited for use of surplus heat from the production process and the calculation principles for different types of integrated plants (for co-production of products). One important conclusion from Pettersson and Wickman (2025) is that the RED – and, thus, potential future application of similar criteria for BBP - would benefit from including more concrete examples to clarify the "correct" interpretation.

7.4.2 Options for regulatory implementation

The RED III sustainability criteria for biofuels have been introduced in Sweden as a result of a binding EU directive (Renewable Energy Directive). This means partly that the Member States were forced to implement the regulation within a set time period and, partly, that the detailed provisions and supporting documents (including, for instance, GHG calculation principles and emission default values) have been developed at EU level. The Swedish implementation – through the sustainability legislation[109] - has therefore been able to, largely, refer to the EU directive (with appendices and delegated acts) for details.

The same would be the case if the Swedish implementation of sustainability criteria for BBP await the EU process and potential implementation there. Also, one could assume that the criteria would likely be developed in a similar way for BBP as in RED III, and that the Swedish implementation could be structured in a similar way. Two potential possibilities could be to integrate the criteria in the existing national sustainability legislation for biofuels or develop a parallel, but similar, regulatory framework for BBP. In both cases the Swedish implementation would be directly referring to RED III (or corresponding EU regulation). A note regarding the current EU process for developing sustainability criteria is that they currently seem to primarily be focusing on packaging (in response to PPWR 8.1), and that

[108] Petterson, K. and Wickman, C. (2025). *Classification and sustainability criteria of renewable fuels in the EU – what actually applies?* (In Swedish), Final report from research project, P2023-00841, Swedish Energy Agency. https://www.ri.se/sites/default/files/2025-10/Slutrapport_Klassificering%20och%20h%C3%A5llbarhetskriterier%20f%C3%B6r%20f%C3%B6rnybara%20drivmedel%20i%20EU.pdf

[109] The Swedish sustainability law (Lag (2010:598) om hållbarhetskriterier för vissa bränslen). Updated, in accordance with RED III, as of 2025-06-03. https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/lag-2010598-om-hallbarhetskriterier-for-vissa_sfs-2010-598/

they strive to develop criteria that build on both the RED III and PEF principles (which at this point seem challenging).

In addition to this option for implementation, we have identified three other possible options for Swedish implementation: firstly, a similar national implementation and, secondly, two simplified alternatives (see Table 4).

The first option (mid column in Table 4) is the approach described in Section 7.4.1. It would require legal implementation in a similar way as for the "EU case" and the RED III sustainability legislation could probably be used in a similar way. However, the Swedish authorities would then be responsible for detailing all provisions and to develop all supporting documents. This could be done, in collaboration with industry, but would require sufficient resources.

Simplified alternatives for national implementation (right column in Table 4) could either be to focus on the feedstock related criteria only or to, instead of specifically developing sustainability criteria, require certification according to existing certification schemes that currently can be and are used to certify biobased chemicals and plastics (see Section 6.3.2).

Below, some further reflections on the implementation of the two simplified alternatives, together with an alternative development of an even more comprehensive approach are included. The latter might mainly become relevant as an alternative development of the process on the EU level.

Table 4 Alternatives for regulatory implementation. The grey row includes a short description of the option, while the light blue row includes implications for Swedish implementation.

EU (assumed, likely, approach)	**National implementation of criteria, before EU**	**National implementation – simplified alternatives**
Implementation of PPWR 8.1 = packaging "RED" approach: principles in regulation; modular default values; recognized certification schemes (Aligning with "RED and PEF". Include benefit of recyclability/recycling.)	Similar approach as EU, but earlier On level according to "approach in focus" (see Table x) Can be adapted to type of planned policy measures.	(1) Implement RED III criteria for feedstock only. (2) Link criteria directly to existing certifications (ISCC PLUS etc).
Implementation by specific law (jfrt "hållbarhetslagen").	Implementation by specific law (jfrt "hållbarhetslagen").	Can refer to existing systems/regulations.

Referring to EU documents for all details.	Development of national supporting documents: - GHG calculation principles - Fossil comparators - Modular default values - Method for ensuring compliance (e.g. certification) RED III principles and data can still be used for first steps in value chain.	(1) Not adapted to BBP – value chain differences not accounted for. (2) Approved certification systems need to be identified. Mass balancing principles in certification systems can be criticized.

IMPLEMENT CRITERIA FOR FEEDSTOCK ONLY

The implementation of RED III criteria for feedstock only, would enable direct use of the existing RED III regulation, on both the EU and Swedish level. The regulation could refer to the existing sustainability law but would probably need to include specific routines for reporting of compliance, since the current procedures are linked to the producer of biofuels.

A simplified approach on this level could also include feedstock GHG emissions (cultivation, land use management and transport), since RED III calculation provisions and default data include also these steps. The resulting emissions cannot be compared to corresponding fossil emissions in any meaningful way, but a criterion to avoid the "worst" feedstock combinations could still be specified.

A simplified implementation of criteria at this level would not be adapted to the specific value chains and challenges of BBP and will not in itself account for differences between value chains or varying end uses. It would be possible to introduce regardless of type of policy measure but be more relevant if potential policy measures are targeting the feedstock use as well.

LINKING SUSTAINABILITY CRITERIA DIRECTLY TO EXISTING CERTIFICATION SYSTEMS

Another simplified option may be to, instead of directly developing criteria, require that producers of bioplastics have their products certified by a CoC certification system to be eligible for a certain policy measure. Certification would then have to be made by existing certification schemes that currently can be and are used to certify biobased chemicals and plastics (examples of such schemes are ICSS PLUS, REDCert2 and RSB AP).

The authorities would still need to specify the minimum requirements of the certification schemes and - based on that - need to identify which certification systems that would be "approved" and what "version" of

certification that would be required. The latter could, for instance, involve requirements of GHG emission calculations, which are not always obligatory. In some of the schemes it is also possible to be certified in relation to different chain of custody approaches (e.g. controlled blending or mass balance).

At a general level, the CoC approach applied by these systems, allow for more extended versions of mass balancing, including what is often called free attribution. This means that certification systems can be criticized.

COMPREHENSIVE CRITERIA SPECIFIED ON PRODUCT LEVEL

The approach to GHG emission criteria outlined in Section 7.4.1 could also be extended to specify GHG criteria on final product level. This would, partly, imply that GHG criteria were specified for a large number of specific final products, partly, it would mean that the resulting GHG emissions calculated, at least in principle, corresponded to the actual life cycle emissions of each product.

The principles for determination of fossil comparators and GHG emission default values would be the same but involve more value chain steps and a much larger number of process routes.

For this approach, the modular approach is even more important. It would then involve calculation of default GHG emission values modularly for fossil and biobased platform chemicals as well as for feedstock independent processes later in the value chains (from platform chemicals to polymers and from polymer to final products).

One could also link these provisions to the rules for PEF and Plastic LCA, so that results include information about biogenic carbon, in accordance with the rules about additional technical information for intermediate products.

8. National policy measures to advance biobased plastics

Below, in Sections 8.1 to 8.5, various examples of policy measures that could potentially be used to advance biobased feedstock in plastics at the national level are described. The overview is based on discussions with the Swedish EPA, and on literature that refer both to policies related to BBP specifically and to other policy areas with similar challenges.

This study does not include development of any detailed policy design, but at a general level, implications of these choices for BBP are further discussed and compared in Section 8.6.

The policy examples in the sections 8.1-8.5 below are discussed from the perspective of *national* adoption. However, the list can be compared with the policy options identified by the Trinomics study at EU level. [110] This study analysed especially four alternatives (in addition to doing nothing):

- Mandatory labelling on sustainable biobased content for plastic products (relying on a certification methodology and scheme, potentially incorporated into the EU Ecodesign legislation);
- Mandatory or preferential use of BBP with regulation that prescribe under which circumstances BBP should be mandatory or preferred to use;
- Green public procurement (GPP) through incorporation of BBP in the existing EU GPP criteria (see also below); and
- Voluntary use of a label, which is promoted and overseen by the EC (similar to first option).

The study recommended to use the studied policy options in series, starting with the least complicated to provide a proof of concept and to facilitate the development of experience and an evidence base, prior to implementing a more complicated option For example, the implementation of a voluntary scheme could be used as a 'pilot' for mandatory labelling, and the implementation of green public procurement could be used as a 'pilot' for mandatory/preferential use of BBP.

[110] European Commission: Directorate-General for Environment, Trinomics, Wageningen and Wood (2022). *Biobased plastic – Sustainable sourcing and content – Final report*, Publications Office of the European Union. https://data.europa.eu/doi/10.2779/668096

8.1 Green Public Procurement

8.1.1 General background on GPP

Public entities (authorities, municipalities, regions) that seek to reduce their environmental impact from procured goods and services throughout their life cycle can adopt Green Public Procurement (GPP). The basic concept of GPP relies on having clear, verifiable, justifiable, and ambitious environmental criteria for products and services, based on a life-cycle approach and scientific evidence base[111].

The European Commission (EC) has been developing voluntary GPP criteria for several product groups, but none refer to bioplastics. Procurement is mentioned in the Trinomics report[110] as one of the more frequently used policy measures to promote the market development of biobased material in EU member states.

In a project carried out in 2021[112], a number of public procurers from regions and municipalities were interviewed and their criteria for procurement of BBP in different product groups were identified and described. The project concluded on the following recommendations:

> *" The procurement of more sustainable plastic products can ask for products from biobased or recycled plastic. The product should be produced from biobased feedstock that does not come from land where the production of feedstock competes with food production or land that previously was covered with rainforest.*
>
> *Furthermore, the feedstock shall be free from GMO crop and palm oil.*
>
> *Complementary aspects to consider in the procurement criteria:*
>
> *- The requirements on the level of biobased content shall be as high as possible based on the current market situation. Increasing the percentage successively to speed up the transition to biobased content is encouraged.*

[111] European Commission (n.d.) *Green Public Procurement.* https://green-forum.ec.europa.eu/green-business/green-public-procurement_en

[112] Chalmers Industriteknik (2021). *Ökad kunskapsspridning och diskussion om biobaserade plaster.* https://goteborg.se/wps/wcm/connect/ff18309c-ce2c-463b-b17a-2fc650d818fe/%C3%96kad%2Bkunskap%2C%2BSlutrapport%2C%2B210928.pdf?MOD=AJPERES

- The use of mass balance certified raw material to speed up the transition to biobased content is encouraged.

- The climate impact in a life cycle perspective must be verifiably low/lower (to be verified by LCA or equivalent analysis).

- The product must be designed for circularity, which means that it primarily must be reusable and secondarily recyclable."

8.1.2 Examples of Green Public Procurement for biobased plastics

Long before the adoption of the ESPR (see Section 4.2), the European Commission's Executive Agency for Small and Medium-Sized Enterprises (EASME) published a user-friendly guidance and information materials in 2017 to facilitate the uptake of innovative biobased products in procurement. Training materials and some factsheets on the innovation potential of biobased products in a couple of groups are still available, but the guidance itself has not been found, neither the meta-database containing links to relevant biobased products that is referred to in the leaflet about the publication of the guidance.

The European Commission also developed voluntary criteria documents for green public procurement (GPP) of 14 product groups. The documents were published between 2012 and 2021. None of these refer to biobased plastic. This is also the case for the more recently published practical guides, intended for authorities awarding public contracts, for the use of the EU Ecolabel in GPP of four product groups.

The impact of procurement on the uptake of BBP has not been assessed in the current study, but the promotion of BBP through the European GPP instruments is likely limited.

The National Agency for Public Procurement in Sweden has developed criteria for public procurement of single use textiles in healthcare, where the supplier in the tender must certify that plastic material used within the contract consists of at least 30% biobased plastic material. The calculation may use mass balance principles based on data from a defined period.

8.2 Blending obligations

8.2.1 General background on blending obligations

One policy option for the promotion of BBP is a blending, or quota, obligation, i.e. mandatory minimum biobased content in material produced in Sweden and/or final products introduced on the Swedish market.

In 2019, The Organisation for Economic Co-operation and Development (OECD) carried out an empirical study to find out what policy instruments that had been introduced for, in a broader sense, a sustainable use of plastics in 50 countries. The study did not investigate BBP as such but stated that they offer potential as long as land-use impacts are managed. OECD recommended blending obligations as one of the more effective policy measures since it contributes to increase circularity and incentivises the reduction of virgin plastic material. However, the study did not investigate the existence of any blending obligations as a means of increasing the share of BBP specifically.[113]

Blending obligation on recycled plastics was discussed in a study by CE Delft (2022), referred to in Naturvårdsverket (2024)[114]. Two alternative models were analysed: blending obligation linked to

- plastics in products, both produced and imported to a specific market,
- raw material/polymer granulates, both produced and imported.

For various reasons, the authors advocated the second option, although this alternative also would be associated with drawbacks, e.g. disadvantages for domestic production of polymer granulates, both for domestic final products and for export of polymer granulates, in comparison to imported products.

Naturvårdsverket (2024) found that any blending obligation, implemented nationally for product groups that are also subject to European law, may interfere with the fundamental economic pillar of free movement of goods and services within the inner market. [114] In the context of the current report, such European laws would likely be the PPWR, the Construction Products Regulation, and the many delegated acts, issued based on the Ecodesign Directive (ESPR), that are to be expected.

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[113] OECD (2022). *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*, OECD Publishing, Paris, https://doi.org/10.1787/de747aef-en.

[114] Naturvårdsverket (2024). *Rätt plast på rätt plats. Bilaga 2 - Styrmedelsanalys.* Slutredovisning av regeringsuppdrag, ärendenummer NV-09904-21. 2024-03-14. https://www.naturvardsverket.se/494311/globalassets/amnen/plast/hallbar-plastanvandning/ratt-plast-pa-ratt-plats-bilaga-2.pdf

8.2.2 Example of blending or quota obligations

One example of a blending obligation, however targeting recycling, is the packaging and packaging waste directive (PPWR) introduces minimum recycled content targets for 2030 and 2040 for plastic packaging. [115]

THE DUTCH NATIONAL CIRCULAR PLASTIC STANDARD (NCPN)

A similar example, which is planned to be implemented nationally, is the National Circular Plastic Standard in the Netherlands. This initiative sets a combined mandatory proportion of recyclate plus biobased polymers in subproducts and end products. The obligation applies to all polymers processed into subproducts and end products in the Netherlands for the Dutch market.

In December 2024, a notification was submitted to the EC. When and if it is approved, the NCPN is planned to enter into force in 2027 and gradually increase the minimum proportions, aiming for the application of 25–30 % recyclate and biobased polymers in subproducts and end products by 2030. Thus, the standard does not differentiate between recyclate and biobased polymers.

Since market parties are free to determine how the obligation is achieved, and rights (hereafter circular plastic units) can be traded among themselves, the obligations will most likely be fulfilled using the cheapest technologies, probably mechanical recyclate. Hence, NCPN will not drastically increase the amount of biobased raw material in the Dutch plastic production and market. Furthermore, the standard only applies to the placing of plastics on the Dutch domestic market. Foreign customers can therefore freely purchase fossil-based plastic products, such as plastics intermediaries, from Dutch producers. European intermediaries (e.g. from Belgium) could then sell these on the Dutch market, since the obligation only applies to products that are processed in the Netherlands.

In the notification to the European Commission and in the draft amendment of the Dutch Environmental Management Act, the Dutch government claims that, on average, 2.5 kg of CO2 emissions per kg of plastic produced can be reduced by replacing polymers made from virgin fossil raw materials with polymers made from recyclate or biobased raw materials [116].

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[115] European Commission (n.d.) *Packaging waste.* https://environment.ec.europa.eu/topics/waste-and-recycling/packaging-waste_en

[116] European Commission (2024). *Notification Number : 2024/0707/NL (Netherlands) Amendment of the Environmental Management Act in connection with the introduction of an annual obligation for circular polymers, circular polymer units, and a register of circular polymer units (legal amendment for a Circular Plastic Standard).* https://technical-regulation-information-system.ec.europa.eu/en/notification/26528/print

THE DUTCH SUBSIDY FOR CONVERSION TO CIRCULAR PLASTIC PRODUCTION

From April to October 2025, companies that make plastic semi-finished and finished products out of polymers or adds additives or fillers to polymers to give them new properties can apply to the Dutch government for financial subsidies for production trials using recycled or biobased plastic. The companies that apply for the subsidy need to submit a budget estimate, containing the number of hours to be spent on the production trial, the costs of operating the machines, the materials used, and third-party costs.[117].

8.3 Reduction of taxes

As mentioned above (see Section 8.2.1) OECD has studied policy instruments in 50 countries, introduced for, in general terms, a sustainable use of plastics. In addition to blending obligations, OECD recommended taxation of plastics, with a possibility for tax reduction based on recycled or biobased content, as another effective policy measures since it would contribute to increase circularity and incentivise the reduction of virgin plastic material.[118]

In EC (2022)[110], a tax on virgin fossil-based plastics was considered unviable due to lack of political feasibility and low efficiency:

- A tax requires unanimity voting in the European Council, which is an unlikely event.
- A tax could increase the competitiveness of BBP.

However, the report continues, the price gap between biobased and fossil-based plastics is larger than the VAT (value added tax) rate, which was used as an example. It is not clear which member state VAT rate the authors refer to, but they seem to suggest that if a tax is introduced, it must lead to higher costs for the user of fossil-based virgin plastics than the costs for BBP.

8.3.1 Examples of taxes on plastics

There are some examples of national taxes focusing on plastic, although none specifically target biobased plastic, but rather intend to reduce use of disposable plastics in general or to increase recycling. In the latter case the tax is reduced for plastic that either contain recycled material or recyclable material.

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[117] Business.gov.nl (n.d.). Conversion to circular plastic production subsidy. https://business.gov.nl/subsidy/circular-plastic-production-subsidy/

[118] OECD (2022). *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*, OECD Publishing, Paris, https://doi.org/10.1787/de747aef-en.

Sweden introduced a tax on plastic bags in May 2020. The price for the consumer for the bags rose, and the plastic bag consumption decreased by three quarters in four years. However, in connection to a political settlement, the tax was abolished in November 2024.

The UK introduced a plastic packaging tax, that is also a sort of blending obligation, on the 1 April 2022. It applies to all plastic packaging that does not contain at least 30% recycled material and targets both UK producers and importers of plastic packaging. The tax also covers packaging that is already "filled" when imported into the UK. The tax is charged at a rate of about £223per tonne (from the 1 April 2025). Two types of packaging qualify for the tax: either used in a supply chain or for single use by a consumer. Some plastic packaging is exempt from the tax e.g. longer-term primary use. The tax does not apply to export of the packaging outside the UK. Two main groups are responsible for paying plastic packaging tax – importers and manufacturers.

Spain has also introduced a plastic tax. This tax applies to the use of packaging that contains plastic and cannot be reused. Packaging is considered non-reusable when it is not intended, designed, or marketed with a view to accomplish multiple rotations throughout its life cycle, or to be refilled or reused for the same purpose for which it was originally intended. The tax is charged on the amount of non-recycled plastic used in non-reusable plastic packaging, when the packaging is delivered. The tax entered into force on the 1 January 2023 at a rate of €0.45 per kilogram.[119]

8.4 Fees

In contrast to taxes, that are compulsory and 'unrequited' charges, fees must be 'requited', which means a direct service is received for the payment. A fee can be compulsory or voluntary.[120] A study by Naturvårdsverket (2020), that designed and analysed instruments that could reduce the amount of fossil-based plastics in products and in waste to incineration to reduce the emissions of GHG, rejected fees as policy instrument. The reason was that since they require a direct link between the payment and the service received, their implementation becomes additionally complex and are

[119] KPMG (2021). *Plastic Tax.* https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2021/09/plastic-tax.pdf

[120] Office for National Statistics (2019). *Taxing decisions. How the ONS tells the difference between taxes and fees – and why it matters*. https://blog.ons.gov.uk/2019/05/31/taxing-decisions-how-the-ons-tells-the-difference-between-taxes-and-fees-and-why-it-matters/

associated with a series of administrative and legal issues.[121] This conclusion is thus valid for introduction of new fees.

In Sweden, there exists however already a fee system that includes plastic packaging. As part of the extended producer responsibility, all manufacturers of packaging[122], or their representative, must be affiliated to an approved producer responsibility organization (or provide a producer responsibility organization) approved by the Swedish EPA. The producer (or its representative) pays fees to the producer responsibility organisation[123]. The fees are differentiated between material (for paper and plastics also between two levels of recyclability) and charged per kilogram of packaging material.

To incentivise the use of BBP, the plastics packaging fee could be differentiated between raw materials for biobased and fossil-based material, where the difference between the biobased and fossil fees would need to, at least, compensate the producer for the higher price on biobased packaging material. The producer would need to comply with a new regulation, similar to Hållbarhetslagen for biofuels, with land use based sustainability criteria similar to RED and adapted GHG reduction criteria, according to the principles discussed in Section 7.4 . The producer responsibility organisation would then be compensated for the lower income from the collection of the verified amount bio-based material. However, the fact that the packaging fees are fees, and not taxes, must be looked into; the difference in fee between fossil and biobased material might need to be implemented as a tax.

8.5 Operational aid through contracts for difference

Policy measures could also be developed in the form of operational aid, aiming at compensating for the higher price of biobased raw material and/or biobased value chain. Such operational aid can be designed in a number of ways. One example is the Swedish operational aid for biogas production

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[121] Naturvårdsverket (2020). *Styrmedel för minskad klimatpåverkan från plast.* Rapport 6928, https://www.naturvardsverket.se/4a4388/globalassets/media/publikationer-pdf/6900/978-91-620-6928-5.pdf

[122] There are exemptions, see i.e. Naturvårdsverket (n.d.). *Extended producer responsibility for packaging*. https://www.naturvardsverket.se/en/guidance/extended-producer-responsibility-epr/producer-responsibility-for-packaging/ (Accessed 2025-11-15).

[123] Svensk Författningssamling (2022). *Förordning (2022:1274) om producentansvar för förpackningar.* https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/forordning-20221274-om-producentansvar-for_sfs-2022-1274/

that is upgraded to biomethane and/or produced from manure. This aid is pre-paid based on specified aid per kWh delivered, and each operators' estimated production volumes. The amount is adjusted the following year based on actual production, which can lead to requests for repayment.[124] Within this study, it was not possible to include a broader review of different forms of operational aid. The choice made was therefore to focus on the type of aid known as Contracts for Difference (CfDs).

CfDs were first introduced as a form of financial agreement between two parties to regulate the difference between the market price (or current price) and a reference price (or initial price) of an underlying asset. At the closing of the contract a payment equal to the price difference is made between the parties, the direction of which is determined by whether the market/current price is higher or lower than the initial/reference price.

Similar contractual agreements have been used to subsidize renewable electric power generation in, e.g., the UK and might be useful to support increased uptake of bioplastics. This section gives a brief introduction to the UK CfD-scheme and discusses the key (high level) steps required to develop a similar scheme to subsidize bioplastics.

8.5.1 UK CfDs for energy

The UK CfD system is designed to reduce the financial risk faced by developers of renewable power generation – while avoiding overcompensation – by offering them a fixed, long-term electricity price[125]. During their project development phase, renewable power generators can be awarded CfD contracts with a government-controlled company ("LCCC") as the counterpart. After commissioning, the generator receives payments (per produced MWh) from LCCC whenever the wholesale market price is lower than the "strike price" set by the contract, to top up the market price to the strike price. Conversely, if the market price rises above the strike price, the generator makes payments to LCCC. The payment mechanism is illustrated in Figure 9.[126,127]

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[124] Svensk författningssamling (2022). *Förordning (2023:225) om statligt stöd till produktion av viss biogas* (in Swedish). Förordning (2022:225) om statligt stöd till produktion av viss biogas | Sveriges riksdag

[125] UK Government (2016). *Contracts for Difference.* https://www.gov.uk/government/collections/contracts-for-difference (Accessed 2025-11-01)

[126] Low Carbon Contracts Company. *About the CfD scheme*. https://www.lowcarboncontracts.uk/our-schemes/contracts-for-difference/about/ (Accessed 2025-11-01)

[127] Cfd Allocation Round Resource Portal. *Low Carbon Contracts Company*. https://www.cfdallocationround.uk/about/low-carbon-contracts-company (Accessed 2025-11-01)

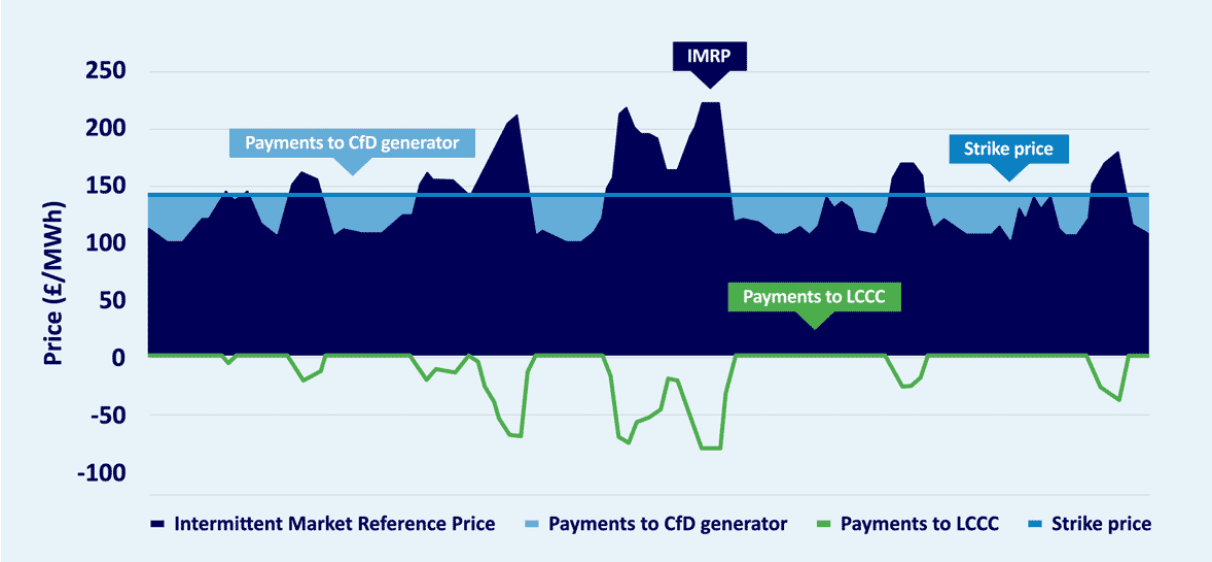

Figure 9 Payment mechanism of the UK CfD-sheme. Figure from [131].

The CfDs are awarded through reverse auctions during which the project developers submit sealed bids containing their planned capacity (MW), target dates (simplified: its planned commissioning date) and its proposed strike price (£/MWh). The bids are ranked by strike price in ascending order and awarded contracts until an auction limit (capacity or budget[128] cap) is reached. All awarded contracts will have the strike price of the last (i.e., highest) awarded bid – this is the auction clearing price[129]. Note that each eligible generation technology has an associated cap on the strike price ("administrative strike prices") that cannot be exceeded even if the clearing price is higher.[130,131]

In general, several auctions will be held during an allocation round – each with slightly different rules regarding e.g., eligible technologies and the clearing mechanism. For example, some auctions use "Maxima clearing" which allows for different clearing prices for different technologies (e.g., one clearing price for all awarded solar projects (equal to the price of the

[128] Note that the bids themselves do not include a total cost or budget impact. The budget impact of each bid is estimated ahead of the auction by the auction operator.

[129] In auction design, this is referred to as "paid as cleared".

[130] Department for Energy Security & Net Zero (2025). *Contracts for Difference Scheme for Renewable Electricity Generation - Allocation Rounds 7 and 7a: Contract Allocation Framework, 2025.* https://assets.publishing.service.gov.uk/media/6880ff3f9fab8e2e86160f7a/ar7-contract-allocation-framework.pdf

[131] Department for Energy Security & Net Zero, NESO, Low Carbon Contracts Company & Ofgem (2025). *Introduction to CfD Allocation Round 7.* https://allocation-cms-eu-west-2-files20240731180525306000000004.s3.amazonaws.com/documents/AR7_Launch_full_slidepack_-_29_July_2025.pdf (Accessed 2025-11-01)

highest awarded solar project) and a different clearing price for all awarded wind projects – both subject to administrative strike prices)[130, 131].

8.5.2 Financial CfDs (for energy)

The UK CfD contracts are production-based meaning that the renumeration is linked to the output of the producing asset. This gives the generator an incentive to always maximize production, i.e., the generator will no longer follow the price signals of the power market. *Financial CfDs*[132] aim to circumvent this drawback by decoupling the renumeration from the generator's actual production. To achieve this, the generator

1. receives a fixed hourly payment from the CfD-counterparty (i.e, the government) that is independent of the generators production and market prices
2. makes a payment to the CfD-counterparty that is calculated as the profit of a *reference plant*. This payment is calculated as the difference between market prices (e.g., the price on the day ahead market) and the production costs of the reference plant (= the profit of the reference plant), times the reference output.

Importantly, the two payments are independent of the actual production of the specific asset that is covered by the CfD. The size of the second payment will be higher during periods with high electricity prices, thus incentivizing generators to increase production during such periods (to cover the cost of the second payment by utilizing the higher power prices). To achieve the overall goal of the CfD – i.e., to provide a guaranteed price to generators without overcompensating them – it is important that the production profile and costs of the reference plant closely match those of the contracted asset. In 2025, the Swedish parliament adopted a new law allowing state-backed financial CfD to support the development of new nuclear power[133,134].

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[132] I. Schlecht, C. Maurer, L. Hirth. (2023). *Financial Contracts for Differences*. ZBW - Leibniz Information Centre for Economics, Kiel, Hamburg. https://www.econstor.eu/bitstream/10419/268370/1/Financial_CfD.pdf

[133] Regeringskansliet (2025). *Så fungerar stödmodellen för finansiering av ny kärnkraft. https://www.regeringen.se/regeringens-politik/karnkraftsfinansiering/sa-fungerar-stodmodellen-for-finansiering-av-ny-karnkraft/* (Accessed 2025-11-01)

[134] Regeringens proposition 2025/25:150. *Finansiering och riskdelning vid investeringar i ny kärnkraft.* https://www.regeringen.se/contentassets/06039e8504de48ad83de3829d101d6f9/finansiering-och-riskdelning-vid-investeringar-i-ny-karnkraft-prop.-202425150.pdf

8.5.3 Considerations for bioplastic-CfDs

A CfD-scheme inspired by the power market CfDs discussed above may be used to incentivize bioplastics-production by offering a guaranteed sales price to producers.

Some key design considerations and challenges are discussed below.

Eligible products and/or technologies

It is not straightforward to decide which products and/or production technologies that should be eligible for a CfD. If tailored contracts are offered to every conceivable type of (consumer/end-use) plastic the resulting support scheme will be very complex. Most likely, it is more feasible to offer the contract at an earlier point in the value chain, e.g., for polymers. Regardless, the fact that "bioplastic" isn't as well-defined a product as "electricity" may pose challenges in the CfD-design (this also has implications for the points below).

Reference market price

A bioplastic-CfD would need a *reference market price* to reflect the revenue that a producer receives for its product without support/aid. For electricity, the transparent pricing on the day ahead markets is a natural reference point for the contract. For plastics, the lack of transparent market data is likely to make an agreement on the reference price more challenging.

Strike price

A correct strike price is important to avoid overcompensation. Competitive bidding through reverse auctions is a way to avoid too high strike prices. However, this requires at the very least two potential producers per auction. This would be a challenge, considering the low number of Swedish producers and the fact that few (if any) producers make products that are similar enough to allow fair competition between them.

In principle, the strike price could also be negotiated between the parties of the contract (i.e., "the government" and a producer). This is, however, likely to put the government at a significant information disadvantage and may lead to overcompensation of the producer.

Alternative: Reduced feedstock price by way of CfDs

CfD-schemes designed to support renewable production "normally" aim to offer producers a guaranteed price for their product – i.e., to *increase* the sales price to a level that is economically feasible for the producer. An alternative approach is to *decrease* the production costs to a feasible level, e.g., by lowering the price of important inputs. This is straightforward for production processes where a feedstock switch is the only difference

between fossil- and bio-based production (e.g., if (a part of) the fossil alkanes and naphtha that are fed to a steam cracker are replaced with biogenic ditto). In such cases, the higher cost of bio-based production is wholly linked to the higher cost of the bio-feedstock, and a CfD-inspired support scheme based on the price difference between fossil- and bio-feedstocks could be used to nullify the cost increase and make bio-based production equally as cheap/expensive as fossil production, see Figure 10.

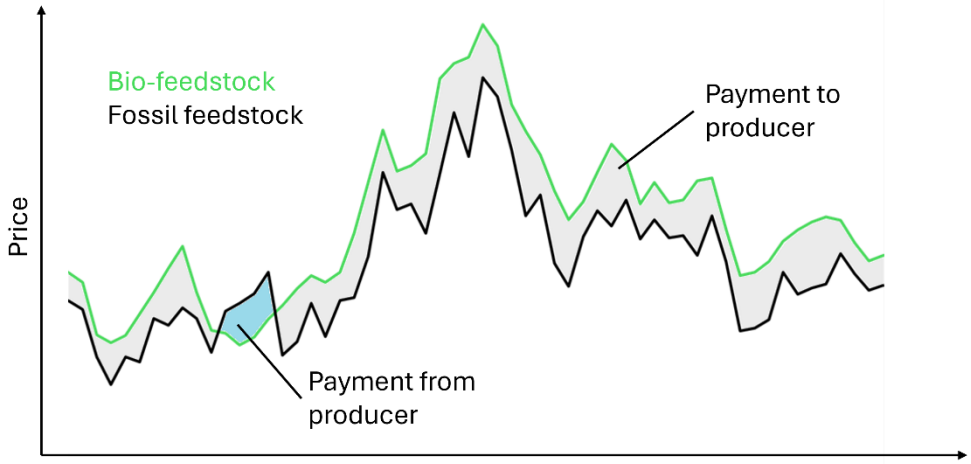


Figure 10 Principal design of a "feedstock-CfD". The bio-plastics producer is paid the price difference between bio- and fossil feedstock. If fossil feedstock is more expensive, the producer pays the difference back to the issuer of the CfD.

This support scheme would be based on two market prices (fossil and bio-feedstock), which negates the need for a contracted strike price and its associated difficulties. Note, however, that market prices for (bio-)feedstock aren't necessarily more transparent than for plastics or polymers.

Although a "feedstock-CfD" as described above may be simpler in its design than a "product-CfD", it has two major drawbacks:

1) The "feedstock-CfD" cancels the entire economic effect of the feedstock switch, thus allowing the plastic producer to maintain its operating margins. These margins may be too high to warrant state aid. In fact, the producer will likely be able to improve its margins by receiving a "green premium" for its new bio-product.
2) Many promising pathways for bio-based production rely on feedstock changes as well as changes in production technology. New production technologies (e.g., gasification-based pathways) are often associated with high CAPEX that cannot be addressed at all by a support scheme that targets feedstock costs – and the feedstock costs may in fact be lower than for fossil pathways.

To address these drawbacks, the terms and pricing of the feedstock-CfD would have to consider more aspects of the production processes – essentially transforming it into a product-oriented CfD.

8.6 Summary of feasibility and implications of alternative policies

Regardless of the type of policy measure, introduction of policies to advance BBP require a parallel introduction of sustainability criteria, that can be linked to the policy. That is, that the policy is designed to incorporate the advancement only to BBP that fulfil the sustainability criteria. Vice versa, since the economic incentive for producing BBP is low, strict regulation of sustainability criteria is not that meaningful without some kind of policy measure that can drive the use of biobased feedstock. The small amounts of BBP that are being produced, without public policy measures are driven by niche markets that are ready to pay a premium for a non-fossil (or less fossil) alternative.

Introducing a national policy in one of the EU member states is complex, for all options. The risk that other overarching policies at the EU level impact the legal possibilities for introduction or infer unexpected and/or unwanted system effects is considerable. Further, ongoing and parallel processes for introducing policies specifically targeting BBP at the EU level need to be taken into account. Also, the multitude of parallel processes and measures specifically aiming at increasing the share of recycled feedstock will be interacting with a potential BBP policy measure.

In the tables below, the feasibility and implications for a number of key aspects of the policy measures described above have been summarized. The policies included in this summary has been determined based on the prioritization of the Swedish EPA. However, it should be noted that there are other measures, for instance other types of operational aid for BBP production facilities, covering part of their running costs, that could be highly relevant.

All policies described above can be designed with different focus and boundaries with respect to, for instance:

- BBP specifically or as an integrated policy aiming at decreasing the reliance of virgin fossil feedstock for plastic production, thus including both biobased and recycled feedstock;

- with a direct focus at increasing the share or volumes of BBP or at its contribution to reducing GHG emissions[135];
- with a focus on intermediate or final products and on packaging or plastics in general; and
- on defined in relation to the country of production or on use (where the products are placed on the market) and in their treatment of imported and exported material flows.

Some of these aspects are mentioned in the tables below, but within this project it has not been possible to include a more in-depth discussion or analysis of them.

Further, it should be noted that there are a number of other important aspects that has not been included at all, since it is impossible to draw any conclusion on effects, without specifying the policy/ies in much more detail – and within the boundaries of this limited study. Such aspects include, for instance: the type and amount of feedstock that may be used by the industry as a result of the policy; the risk of "leakage" of GHG emissions and industry activities to other regions; and the risk of involuntarily impacting the competition between different plastic value chains.

[135] Blending policies for transportation biofuels have, e.g., mostly been aiming at increasing the share of biofuel by volume. In later years e.g. Germany and Sweden have instead introduced policies based on GHG emissions reduction, so that biofuels with better GHG performance are favoured.

	Feasibility (in relation to EU law)	Stakeholders affected	National aspects/ complexity	BBP impact	GHG impact
Common for all	Risk for interference with existing or upcoming policies, i.e. for violation of the principles of free movement of goods and services on the inner market and/or for giving unfair advantage to market actors within this market. Regulations such as PPWR and ESPR restricts introduction of substantive requirements beyond what is included there.	Operators controlling (producing and/or marketing) the products targeted and all upstream operators. Operators controlling the point where a potential GHG emission reduction requirement is introduced (and upstream).	Implies efforts for Swedish EPA to mobilise the Swedish polymer and plastics industry and to provide national policy. Additional efforts (both for Swedish EPA and for industry) to develop potential GHG emission criteria.	Depends on the level of ambition, which is not discussed in this study. Comments in other rows refer therefore primarily to the likelihood and certainty that the chosen ambition level can be reached. If policies are expressed in/related to GHG emission reduction – they would not only give incentives to biobased content but also circularity of this content.	
Quota obligation	Low feasibility because of risk for interference with EU policy	Two options: Producers and importers of plastic products (products	CE Delft (2022) advocates the second option. Complexity depends on which chain of custody method is	Depends on the quota level and design.	Depends on the quota level and design.

	Feasibility (in relation to EU law)	Stakeholders affected	National aspects/ complexity	BBP impact	GHG impact
	(Naturvårdsverket 2024). This is currently being tried by the notification to the EC of the NCPN in the Netherlands, including targets for nationally produced **and** marketed products (see 8.2.2.).	including a certain percentage of plastic) on the Swedish market **or** producers and importers of raw material/polymers on the Swedish market	allowed and how biobased "content" is controlled. Less complex if applied on feedstock level. Quotas based on GHG emission reduction requires methods for calculation and fossil comparators. (Not necessarily GHG criteria.)	Expressed in BBP content – ensures that BBP targets are met but uncertain level of GHG emission reduction (above criteria).	Expressed in GHG emission reduction- ensures GHG emission reduction targets but uncertain BBP impact.
Reduction of tax (or existing fees)	Potentially viable, have been introduced for recycled (and recyclable) content (UK and Spain, see 8.3.1).	Two options: Producers and importers of plastic products (products including a certain percentage of plastic) on the Swedish market **or**	Requires a tax (or fee) that can be reduced. Currently few product- or feedstock-related taxes specific for plastic industry. Complex and politically challenging to introduce new taxes. New fees not viable (see 8.4).	Uncertain effect. Difficult to foresee if tax reduction level provide enough incentive for BBP.	

	Feasibility (in relation to EU law)	Stakeholders affected	National aspects/ complexity	BBP impact	GHG impact
		producers and importers of raw material/polymers on the Swedish market	Potentially possible to link to reduction of existing packaging fees (not investigated in detail). If targeted stakeholders (e.g. plastic producers) and stakeholders affected by tax/fee are different – system for transferring needs to be developed.		
CfD	No evaluation found in literature. Since the system implies support to a limited group of companies, with activity specifically in Sweden, the risk of interference with EU policy may be high.	In the two versions discussed here (see 8.5.3) – producers of intermediate platform polymers/plastics (either by them putting their products on the Swedish market or as buyers of biobased feedstock).	For CfD on intermediate platform plastics: Complexity in determining so called reference price and strike price for lack of transparent market prices and few stakeholders involved, respectively. For CfD on feedstock: Less complex to design and determine prices. Risk of over-compensation and do not capture effects of differences in CAPEX.	CfD on intermediate platform plastics: Can in principle be designed related to BBP share or GHG impact. Same uncertainties in effect for both cases (high risk of inefficient pricing)	
				CfD on feedstock: Relatively certain	

9. Conclusions

The introduction of policies for advancing BBP requires a parallel introduction of sustainability criteria, that can be linked to the policies. That is, that the policies apply only to BBP that fulfil the criteria. Vice versa, strict sustainability criteria are not meaningful without policies driving their implementation. From the analysis of potential sustainability criteria and national policy measures for advancing BBP, the following summarized conclusions can be drawn.

Related to sustainability criteria for BBP:

- Sustainability criteria for the use of biomass as feedstock for BBP safeguard against unsustainable resource use and provide transparency to sustainability claims made. Further, they would contribute to levelling the playing field between use of biomass for energy vs materials (plastics).
- The design of sustainability criteria must account for a trade-off between the desire to ensure sustainable resource utilisation and practical aspects (e.g., limiting the compliance burden) as well as aspects linked to the system transition (i.e., avoiding that the criteria hinder the transition from even less sustainable and easily accessible fossil alternatives).
- The sustainability criteria for BPP should not be stricter than those for bioenergy, why it is recommended that development of BBP sustainability criteria is based on and linked to the bioenergy criteria of the EU RED III. These include land use related sustainability criteria and GHG emission criteria.
- Land use related sustainability criteria can and should be directly based on the criteria used in RED III. The feedstocks potentially used for production of plastics are identical with those used for biofuels. Similar to RED III, these criteria would not be applied to BBP produced from waste and residues, other than agricultural, aquaculture, fisheries and forestry residues. The RED III land use related criteria would correspond to a minimum implementation of sustainability criteria, without preventing any actor from applying higher standards.
- GHG emission criteria can, in principle, be excluded (or introduced at a later stage). However, the inclusion of GHG emission criteria would safeguard against use of bio feedstock and production value chains with a high carbon footprint.
- GHG emission criteria cannot be directly transferred from RED III to BBP. The methodology in RED III needs to be adapted. In this adaptation choices need to be made related to product granularity and value chain position (for which to apply the criteria), product

specific fossil comparators, required savings relative to these comparators, principles for allocation of emissions in co-processing and handling of end-of-life emissions. Substantial development work is needed to develop methodology and emission values (for fossil comparators and default BBP value chains, both for drop-in and substitution situations).

- When/if GHG emission criteria are introduced, and in relation to the methodological choices mentioned above it is recommended that:
    - To limit the complexity and efforts needed, the GHG emission criteria – including fossil comparators – are defined in relation to a limited number of drop-in platform intermediary plastics and, for substitution plastics, a limited number of final products.
    - To enable the industry to develop stepwise towards more biobased raw material, the chain of custody principle used should allow for co-processing and a certain level of mass balancing when allocating emissions to different products. Currently, the LCA based frameworks do not include such methods, and therefore the most feasible approach would be to align as closely as possible to the provisions and principles used by the RED III.
    - End-of-life emissions should be included, based on national share of end-of-life treatments for specific plastics/product group. If the end-of-life phase of the bio- and fossil value chains is identical, the difference between them will equal the emissions from stoichiometric combustion of the fossil and biobased carbon content, respectively.
    - To avoid imposing too costly regulations, a list of default values should be developed for the value chains included, following the same modular approach that has been used for the RED III. Operators who want to claim higher emission reductions than the default value would need to demonstrate this by providing actual values, calculated according to the same provisions as for the default values.
- Simplified approaches to implementing national sustainability criteria could be to implement RED III land use related criteria only or link criteria directly to existing certification systems.

Related to national policy measures for advancing BBP:

- Introducing binding national policy measures in one of the EU member states in relation to BBP is complex, since there are a multitude of parallel EU regulations affecting the market and the regulatory possibilities.
- Policies can be designed with different focus and boundaries, e.g. including biobased and/or recycled feedstock, and aiming primarily

to increase the amount of BBP or to reduce GHG emissions from plastics. Further, the scope – and thus the products, markets and trade flows that are affected - impacts the conditions for the implementation and its effect substantially. Further, there may be other types of relevant policy measures, for instance other types of operational aid relevant for BBP production, than those that have been included in the review of this study.

- The introduction of national blending obligations and the development of new national fee systems have in earlier analyses been considered unfeasible due to the risk of them interfering with EU regulations. However, a blending obligation system in the Netherlands is currently being tried and the result of this may impact this conclusion.
- One aspect of a system based on contracts for difference – namely that fact that it would infer support to a limited and geographically defined group of companies – implies that it may have a high risk of interfering with EU policy. However, no deeper analysis of this risk has been carried out.
- Reduction of taxes or of existing fees may be potentially viable, but effects are uncertain.

Further development and increased production of BBP thus has the potential to contribute to decreased dependence on fossil resources and reduced climate impact from plastic value chains. It is possible to move forward at the national level, but the implementation of complete sustainability criteria at EU level and binding policy measures comes with significant methodological and regulatory complexities and the development will require substantial resources. A potential strategy could therefore be to, in anticipation of EU wide developments, implement a simplified approach for sustainability criteria, for instance based on land use related criteria only, and initially link them to the implementation of green public procurement, voluntary labelling systems etc. Policy and criteria could then be gradually strengthened in tandem, and, ideally, in alignment with EU as a whole and with ongoing methodological development.

Appendix 1. Interviewees

1. Saffron Johnsson, Sustainability Business Development Manager, PVC, Ineos/Inovyn
2. Maria Edqvist Schultz, Head of Sustainability, Emballator
3. Anders Fröberg, Vice President Manufacturing Excellence and transformation, Borealis Group
4. Linnea Granström, Climate- and Environmental strategy, Svensk Plaståtervinning
5. Pernilla Åhrlin, Head of Climate and Environmental Policy, and Henrik Oxfall, Head of Plastic, IKEM
6. Mårten Larsson, Senior Policy Advisor, Skogsindustrierna
7. Lorette Du Preez, Head of Sustainability, and Julie Pieters, EU Policy Affairs Manager, European Bioplastics
8. Ioannis Antonopolous, Gea Ortiz Guillermo, Energy Commission, DG-ENV

Appendix 2. Material flows for the Stenungsund cluster

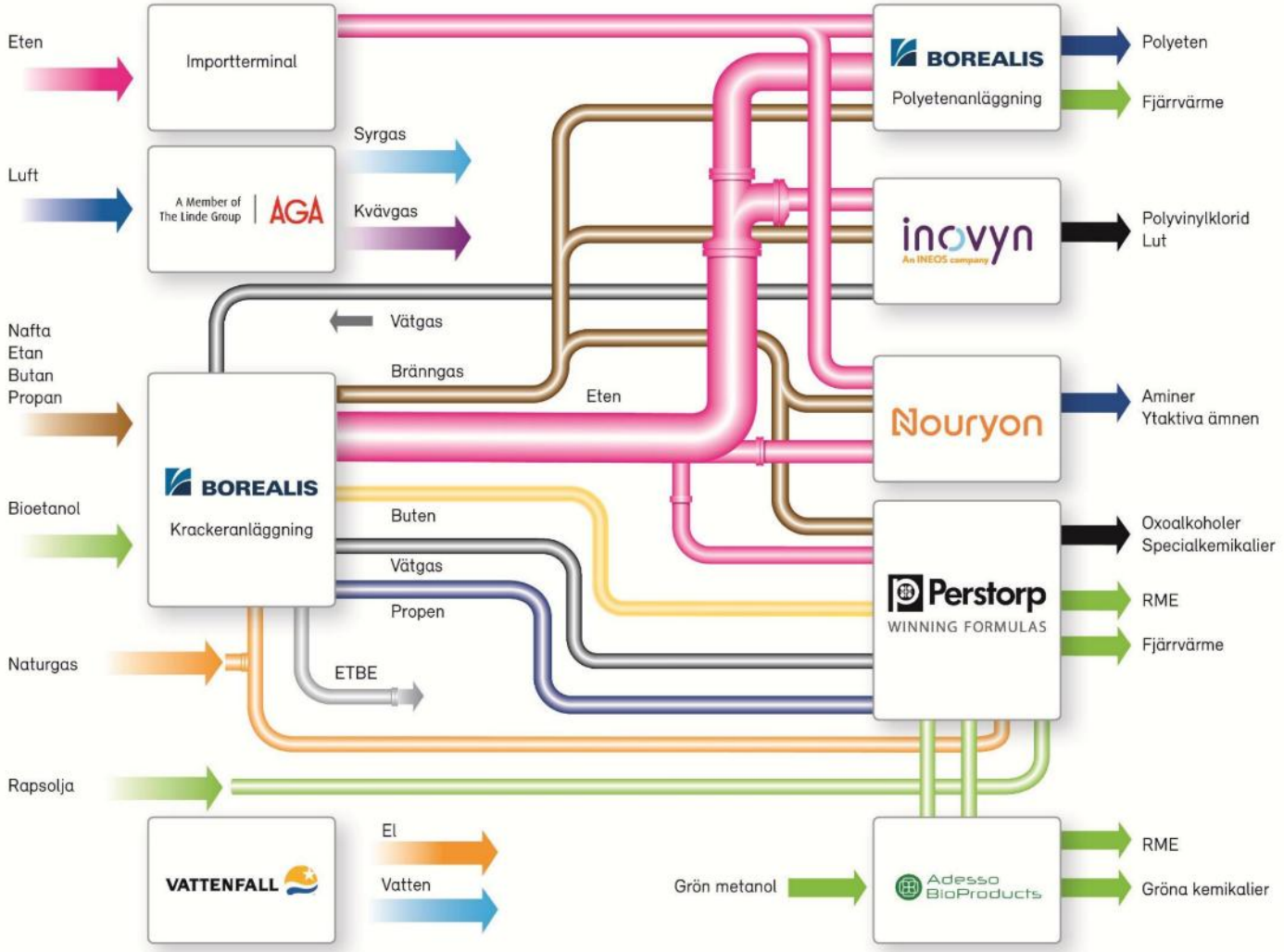


Figure 11 Material flows for the Stenungsund cluster (Borealis, 2022 *Ändringstillstånd Krackeranläggningen - Kemisk återvinning av plast* (Samrådsunderlag). https://www.borealisgroup.com/storage/220301-Borealis-samr%C3%A5dsunderlag-anl%C3%A4ggning-kemisk-%C3%A5tervinning_2022-03-29-091510_vplh.pdf).

Appendix 3. Feedstock to refinery

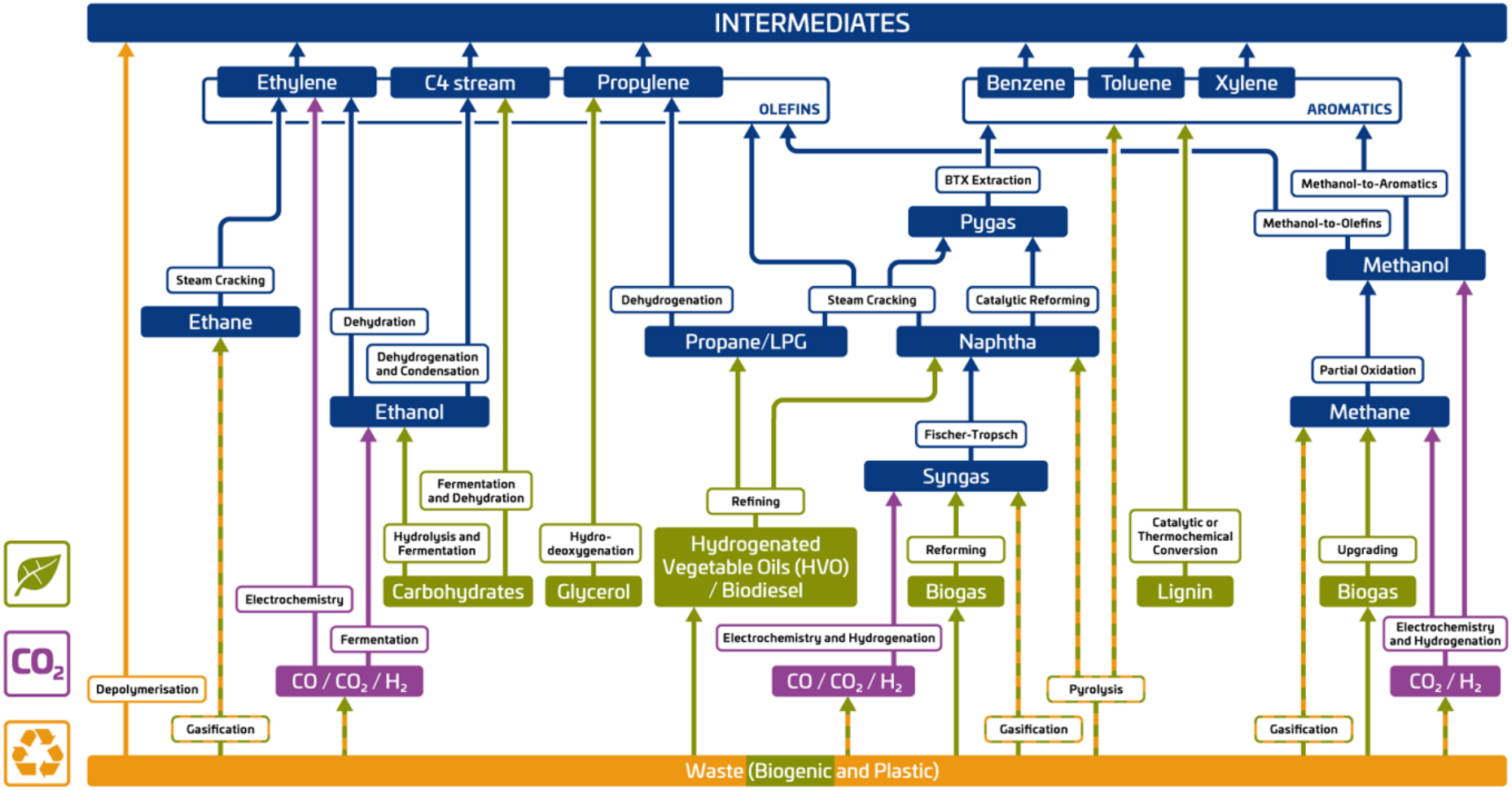
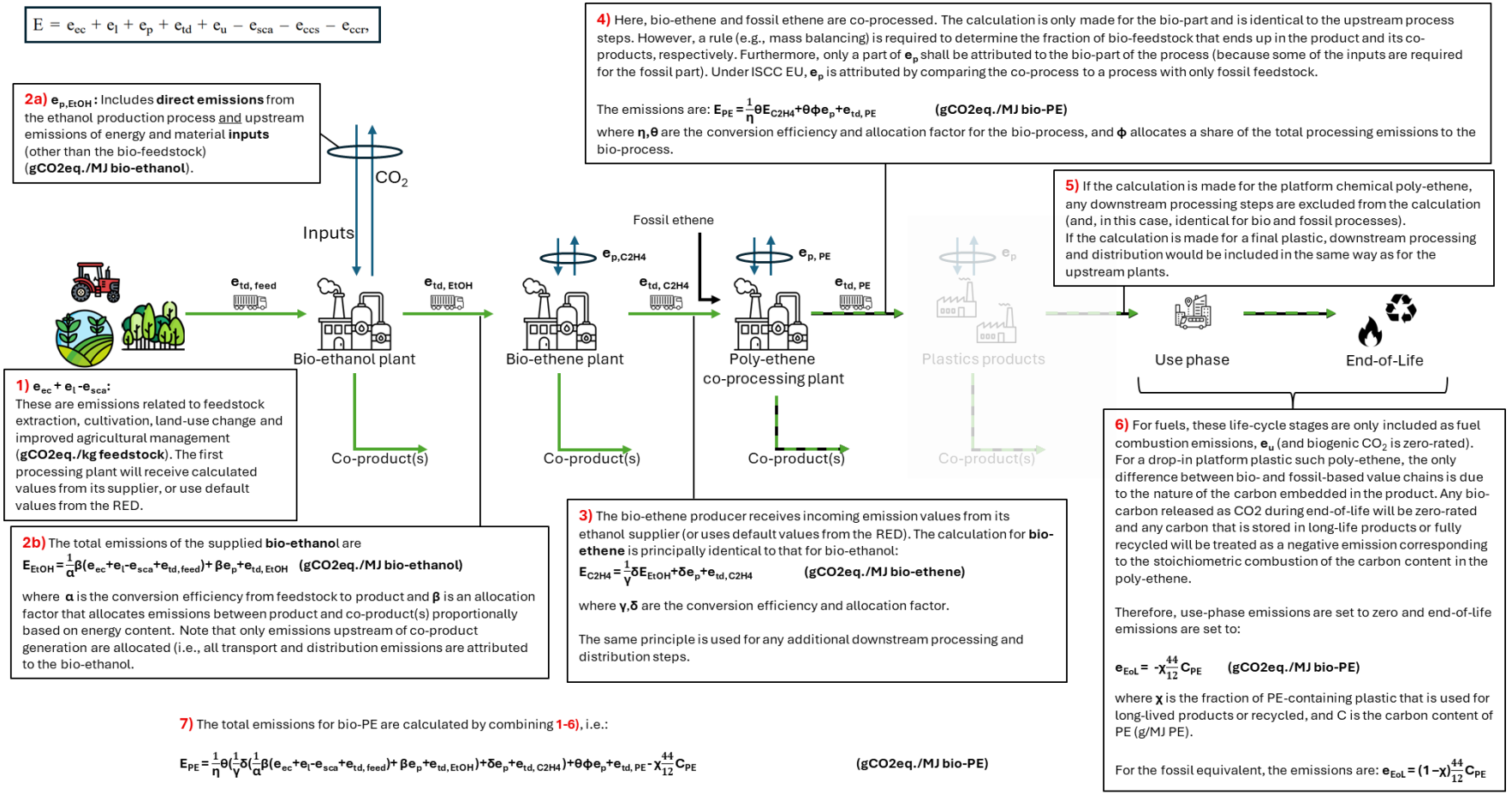


Figure 12 Biobased and/or recycled feedstock to refinery (Nova Institute (2025). *Renewable Carbon Refinery*. https://renewable-carbon.eu/publications/product/renewable-carbon-refinery-png/.)

Appendix 4. GHG emission calculation example



NOTE: The figure decribes the REDIII calculation methodology adapted to bioploymers/bio-plastics and illustrated for the case of bio-ethene production in a co-processing plant. Note that the terms e_{ccs} and e_{ccr} have been excluded these are credits for CO2 that is captured and permanently stored OR used to replace fossil CO2 in production processes. In general, these can be included (along with e_p) in each processing step.

Appendix 5. PEF and P-LCA methods

The Environmental Footprint (EF) methods, comprising the Product Environmental Footprint (PEF) and Organisation Environmental Footprint (OEF), provide harmonised rules for assessment of the environmental impacts of products and organisations throughout the life cycle. They were developed by the EC in 2013 and updated in 2021. [136, 137] Below, only the PEF method will be considered.

The Joint Research Centre (JRC) has elaborated an LCA-based method, the Plastics LCA method[138] (below P-LCA-method), to evaluate the potential environmental impacts of plastic products from different feedstocks. Ensuring full consistency between the P-LCA and the PEF methods was an overarching aim for the development, but other relevant life cycle-based methods and approaches set out in the existing EU legislation were considered, as well as relevant international and European standards. The method was tested and illustrated in several demonstrative LCA case studies, reported in a separate supporting document[139]. In Below some of the methodological issues that are relevant for both fossil and biobased polymers and plastics, addressed in the PEF method and the P-LCA method, are described. The different levels of requirements frequently used in standard development (shall, should and may) are marked in **bold.**

Product Environmental Footprint Category Rules

One fundamental concept in the PEF and P-LCA methods is Product Environmental Footprint Category Rules (PEFCR). The primary objective

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[136] European Commission (n.d.) *About the Environmental Footprint Methods.* https://green-forum.ec.europa.eu/green-business/environmental-footprint-methods/about-environmental-footprint-methods_en (Accessed 2025-09-15)

[137] Commission recommendations (EU) 2021/2279 of 15 December 2021 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021H2279

[138] Nessi, S., Sinkko, T., Bulgheroni, C., Garcia-Gutierrez, P., Giuntoli, J., Konti, A., Sanye Mengual, E., Tonini, D., Pant, R., Marelli, L. and Ardente, F., Life Cycle Assessment (LCA) of alternative feedstocks for plastics production, EUR 30725 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-38145-7, doi:10.2760/271095, JRC125046. https://publications.jrc.ec.europa.eu/repository/handle/JRC125046

[139] Nessi, S., Sinkko, T., Bulgheroni, C., Garbarino, E., Garcia-Gutierrez, P., Giuntoli, J., Konti, A., Orveillon, G., Sanye Mengual, E., Tonini, D., Pant, R., Marelli, L. and Ardente, F., Life Cycle Assessment (LCA) of alternative feedstocks for plastics production, EUR 31085 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-52958-3, doi:10.2760/655230, JRC127175. https://publications.jrc.ec.europa.eu/repository/handle/JRC127175

of a Product Environmental Footprint Category Rule (PEFCR) is to fix a consistent and specific set of rules to calculate the relevant environmental information of products belonging to the particular product category in scope. [140]

Products having similar functions and applications **should** be grouped within the same PEFCR. In some cases, a product category **may** be split into multiple sub-categories. The PEFCR **shall** be structured with a section including the 'horizontal' rules that are common to all products in scope of the PEFCR, and then a section for each sub-category including the specific 'vertical' rules applicable only to that sub-category. In Figure 13 , an example of the structure of such an PEFCR, here for thermal insulation, can be found. Each sub-category **shall** be clearly described in the scope definition of the PEFCR, each sub-category **shall** have its own representative product (RP)[141] and benchmark[142] together with its selection of most relevant processes[143], life cycle stages, direct elementary flows[144] and impact categories[145]. There are additional provisions that **shall** be addressed for comparisons, provided in the PEF methodology.

[140] European Commission (n.d.). *Product Environmental Footprint method.* https://green-forum.ec.europa.eu/green-business/environmental-footprint-methods/pef-method_en

[141] The RP is the basis for the PEF study of the representative product (PEF-RP). The RP may be a final product or an intermediate product. For final products and intermediate products where a benchmark is defined, it is also the basis for identifying the corresponding benchmark.

[142] Benchmark is a standard or point of reference against which any comparison may be made. In the context of PEF, the term 'benchmark' refers to the average environmental performance of the representative product sold in the EU market

[143] The most relevant processes are those driving the environmental profile of a product, these shall be assessed by using data of higher quality compared to the less relevant processes, independently from where these processes happen in the life cycle of the product.

[144] In the life cycle inventory, elementary flows include material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation.

[145] See table 2 in reference 137

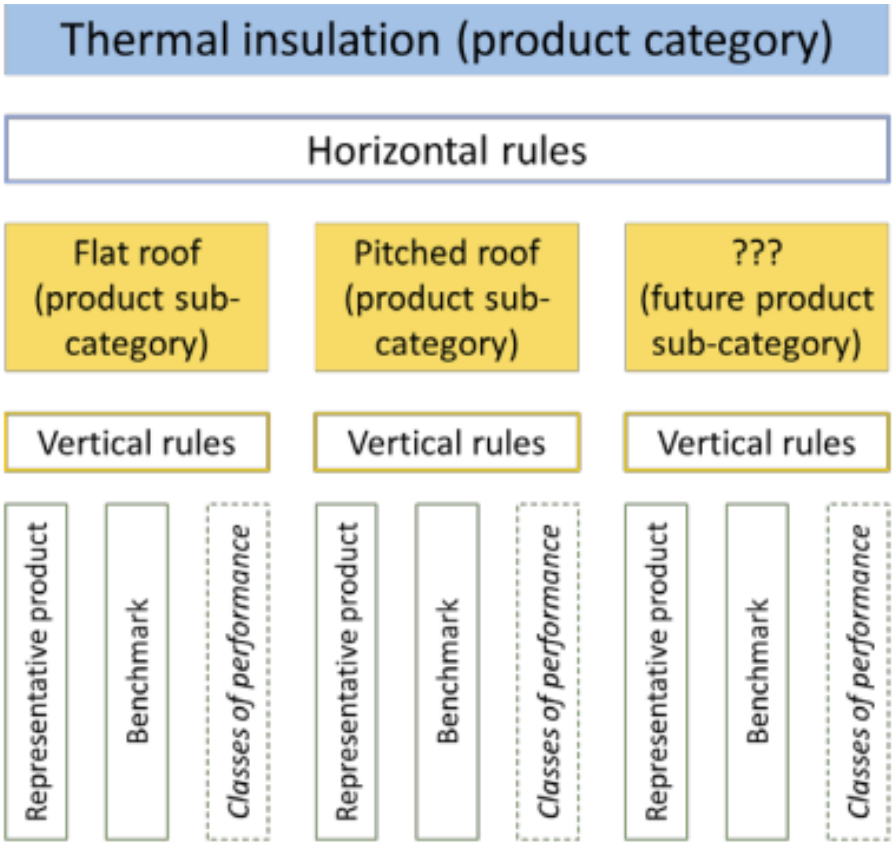

Figure 13 Example of a PEFCR structure with product category specific horizontal rules, various product subcategories, and product sub-category specific vertical rules[137].

Intermediate products

An intermediate product is a product that requires further processing before it is saleable to the final consumer. Polymers and unspecified plastic parts are examples of intermediate products.

In case of intermediate products, the PEFCR becomes a 'module' to be used when developing PEFCRs for products further down the same supply chain. This is equally applicable if the intermediate product can be used in different supply chains (e.g. metal sheets). The development of 'modules' allows for a higher level of consistency among different supply chains that are using the same modules as part of their LCA. Furthermore, the development of 'modules' is essential to keep the number of PEFCRs manageable.[137]

Functional unit

The functional unit (FU) is the quantified performance of a product system, to be used as a reference unit. The functional unit qualitatively and quantitatively describes the function(s) and duration of the product in scope.

The reference flow is the amount of product(s) needed to provide the defined function. All other input and output flows in the analysis quantitatively relate to it. The reference flow may be expressed in direct relation to the FU or in a more product-oriented way.

For intermediate products, the FU is more difficult to define because they can often be converted into a variety of final products, fulfilling multiple functions and whose downstream life cycle is not known. Therefore, a Declared Unit (DU) **should** be applied to such products, and based, for example, on a unit mass (kilogram) or volume (cubic meter) of product. In this case, the reference flow may correspond to the DU.

Life Cycle stages

The mandatory life cycle stages included in a PEF study are raw material acquisition and pre-processing, manufacturing, distribution, use stage and end of life. However, for intermediate products, the use stage and end of life (including product recycling or recovery) **shall** be excluded.

Additional technical information

Relevant potential environmental impacts of a product may go beyond the environmental footprint impact categories[146]. Relevant technical aspects and/or physical properties of the product in scope may also need to be considered. These aspects **shall** be reported as additional technical information.

When the product in scope is an intermediate product additional technical information **shall** include:

- The biogenic and non-biogenic (e.g. fossil) carbon content at factory gate (physical content and allocated content);
- Recycled content[147] of the product (followed by an explicit clarification statement that the environmental implications of using recycled material are already fully considered in the LCA results);
- Results with application-specific A-values[148] of the circular footprint formula (CFF)[149], if relevant.

[146] See table 2 in reference 137

[147] The recycled content and end of life shall be modelled using the CFF at the life-cycle stage where the activity occurs.

[148] The A factor allocates burdens and credits from recycling and virgin material production between two life cycles (i.e. the one supplying and the one using recycled material) and it aims to reflect market realities

[149] The CFF is the formula used to allocate to system under study the burdens of ingoing virgin and recycled material, outgoing recyclable material, disposal, and energy recovery.

Benchmark

The term benchmark refers to the average environmental performance of the representative product (RP)[150] sold in the EU market. The PEFCR **shall** provide the three different types of results (characterised, normalised and weighted results) of the benchmark for each RP for each of the EF impact categories and as a single overall score based on a specific weighting factor. Results **shall** be provided for the total life cycle, and for the total life cycle excluding the use stage.

For intermediate products, benchmarking **may** be excluded.

Comparative assertion

Comparative assertion is an environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function (including the benchmark of the product category). An objective of PEFCRs is to enable such comparisons and comparative assertions in all cases where this is feasible, relevant, and appropriate. For comparisons and comparative assertions, the PEF study **shall** be conducted in compliance with a PEFCR.

Interpretation of any GHG emission saving requirements on biobased polymers and/or plastics based on PEF and P-LCA methods

"Single issue" based (e.g. GHG) comparisons and comparative assertion between fossil and biobased polymers and/or plastics are not allowed since PEFCR is required and a PEFCR cannot be "single issue".

[150] The RP is the basis for the PEF study of the representative product (PEF-RP). The RP may be a final product or an intermediate product. For final products and intermediate products where a benchmark is defined, it is also the basis for identifying the corresponding benchmark.