International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 24s, 2025
https://theaspd.com/index.php

Chain Of Custody: Tracing Sustainability In The European Plastic Sector With A Closer Look At The Mass Balance Approach

Lavtizar Vesna[1], Hayashi Shiko[2]
[1]Holland Circular Hotspot, Maasboulevard 100, Rotterdam, 3063 NS, the Netherlands.
vesna.lavtizar@hollandcircularhotspot.nl
[2]Institute for Global Environmental Strategies, Kitakyushu Urban Center, International Village Center 3F, 1-1-1, Hirano, Kitakyushu, 805-0062, Japan.
hayashi@iges.or.jp

Abstract

Transparency and traceability of materials within supply chains are becoming increasingly important, as reflected in recent EU policies and growing consumer demand. In addition, companies adopting sustainable practices—such as procuring recycled plastics—require robust methods to substantiate and verify their sustainability efforts. This paper explores methods of traceability and transparency in the European plastics sector, focusing in greater depth on the mass balance approach, which is especially relevant in the EU chemical recycling sector. Despite the crucial role that the mass balance method plays in chemical recycling—particularly in enabling recyclers to demonstrate the processing of sustainable feedstock —the allocation rules and accounting methods remain complex and unharmonized. Robust and transparent standards are essential for mass balance to enable wider application and to establish trust and greater credibility among stakeholders. However, where physical segregation of materials can be achieved, chain-of-custody methods with higher inherent credibility should be prioritized and applied instead.

INTRODUCTION: EU policy background on plastic circulation

The European Union (EU) is taking determined steps in the circular economy (CE). In the plastic sector, several CE-related policies have already been put in place and targets set. For instance, the EU has established packaging reduction targets—5% by 2030, 10% by 2035, and 15% by 2040—with particular attention to plastic packaging (EP News, 2024). It has also established ambitious recycling targets for plastic packaging, aiming for recycling to reach at least 55% by 2025 (EC, 2018). To support these objectives, the EU has implemented a plastic levy, a uniform rate of 0.80 EUR per kilogram of non-recycled plastic packaging waste in each Member State (Council Decision 2020/2053, 2020). Additionally, the EU has set a target for PET bottles to contain at least 25% recycled plastic by 2025, calculated as an average across all PET bottles on the Member State's market, with this target increasing to at least 30% by 2030 (Directive 2019/904, 2019).

As there is a tendency for member states and companies to be more sustainable, they also want to prove their sustainability efforts. This, however, requires an established mechanism for transparency and traceability. Corporate Sustainability Reporting Directive (Directive 2022/2464, 2022) and the Ecodesign for Sustainable Products Regulation (Regulation 2024/1781, 2024), which mandates digital product passports for selected products, play a crucial role in promoting transparency in circularity progress. Additionally, the proposed Green Claims Directive (Green Claims, 2025), aimed at protecting consumers from greenwashing, further strengthens the push for credible and verifiable sustainability practices.

For countries seeking to trade with the European Union, understanding the EU policy landscape is essential, as compliance with EU regulations is required when placing products and services on the market. In this context, transparency and traceability are gaining increasing importance.

The aim of this paper is to shed light on the various chain-of-custody methods, with particular emphasis on the mass balance approach and its role within the EU framework. The insights provided are especially valuable for non-EU countries wishing to understand EU directions on traceability, transparency, and the practical applicability of mass balance methods.

Understanding chain of custody types for improved traceability:

Chain of custody models have become essential for manufacturers to demonstrate compliance with regulations and validate the sustainability claims made about their products or materials. The primary drivers

behind these models are government policies, consumer expectations, and growing business demand (Mononen, 2023). To ensure the credibility and reliability of claims made about the product, third party certification is essential (Mononen, 2023).

The International Organization for Standardization (ISO) outlines five distinct chain of custody models: Identity preserved, Segregated model, Controlled blending, Mass balance, and Book and claim model (ISO, 2020). Below we describe Segregation, Controlled blending, and Mass balance (Figure 1), ruling out the Identity preserved model, as it requires a single source of material, which is rarely feasible in the context of plastic recycling. Additionally, the Book and claim model is often criticized for its lack of transparency and is thus also omitted (Caro et al., 2023).

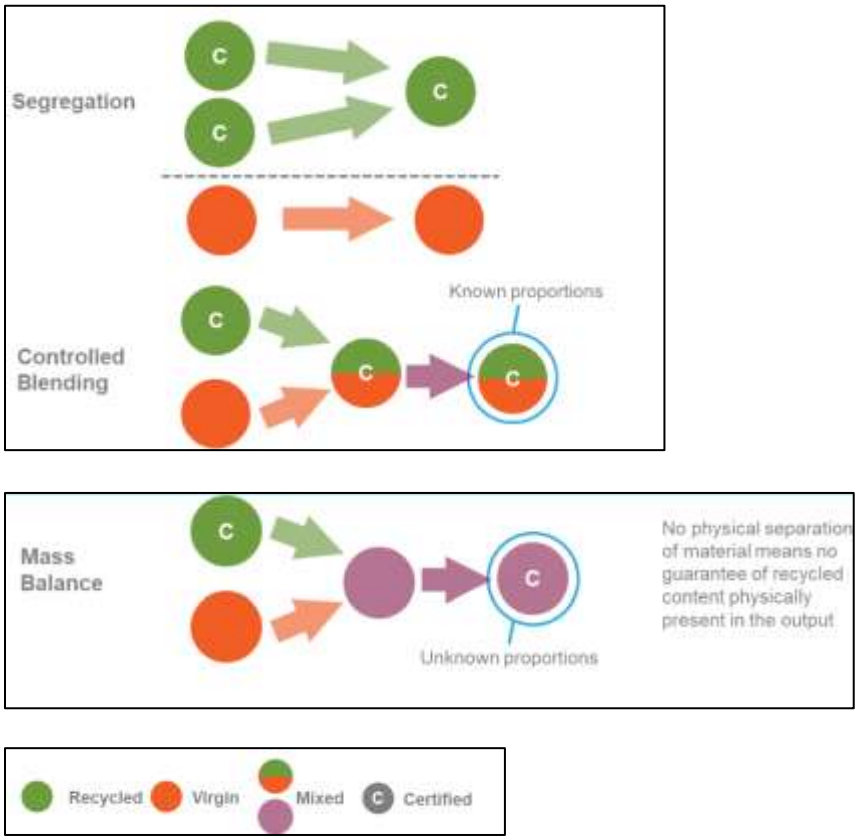

Figure 1: Graphical representation of Segregated model (top), Controlled blending (middle), and Mass balance model (below) (Source: EC & Eunomia, 2022).

In the case of **Segregation**, the input material can come from different sources. Sustainable (recycled or biobased) plastics are kept entirely separate from conventional (virgin fossil-based) ones throughout the process. Mixing of sustainable and conventional inputs is thus not allowed. On the other hand, the **Controlled blending** model allows for the mixing of sustainable plastics with conventional plastics in a known proportion. The content of sustainable plastics in final products is known and is both traceable and verifiable. **Mass balance model** also permits the mixing of sustainable and conventional sources where the proportions of each are known in the process (in a system or supply chain), but in this case, the physical traceability is not involved. Because of that, the amounts of sustainable contents in the final products are less known or unknown (Tabrizi et al., 2021).

The credibility of each method decreases with decreased physical traceability, as illustrated in Figure 2 (Mononen, 2023). As a result, the credibility of the mass balance approach is lower than that of controlled blending and segregation.

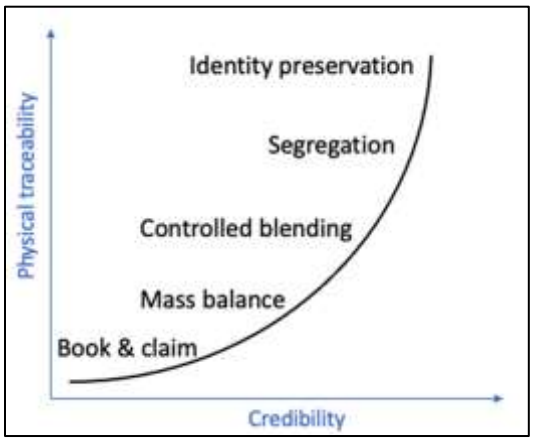

Figure 2: Illustration of the influence of physical traceability on the credibility of different chain of custody models of the final products (Source: Mononen, 2023).

Application of a mass balance approach

Mass balance has been used for years to introduce certified ingredients to consumer products, for example, sustainably harvested wood into the wood supply chain, or certified sustainable cocoa that is being mixed with non-certified ingredients (Rainforest Alliance, 2023). Additionally, as part of the EU targets to introduce a share of renewable fuels and recycled-carbon fuels in the transport sector, economic operators are required to rely on a mass balance system (Directive 2023/2413. 2023).

In the plastic industry, according to Joint Research Centre, which is the European Commission's science and knowledge service, the development of a mass balance model is primarily necessary for chemical recycling, specifically for thermal depolymerization technologies such as pyrolysis and gasification. Other recycling technologies—mechanical, dissolution, and certain chemical depolymerization methods—can utilize segregation or controlled blending that offer higher credibility and transparency (Caro et al., 2023). Chemical processing is especially advantageous for difficult-to-recycle plastics. The plastic is broken down into monomers and can, in further processes, enable production of high-quality recycles that can be applied for food packaging (ISCC, 2025). Not only the quantity but also the quality of recycled outputs matters, which is why, in certain cases, chemical recycling can be a more suitable option. Yet, chemical recycling and dissolution today are less commonly used technologies, treating less than 0.2 Mt of plastics waste in Europe, compared to mechanical recycling, with over 9.0 MT processing capacity (Plastics Europe, 2019). It was estimated that the adoption of chemical recycling along with mechanical recycling could increase Europe's plastic recycling rate to as much as 80% (Lase et al., 2023).

In Europe's chemical recycling sector, the mass balance approach is drawing increased attention especially as it enables the incorporation of recycled materials into existing production processes. As the recycled and virgin feedstocks are combined and mixed within the process, it enables manufacturers to use recycled content without the need for major adjustments to their infrastructure (ISCC, 2025).

There are two subjects that need to be taken in consideration related to mass balance:

a) The accounting method (credit or rolling average percentage method); and
b) Allocation rules

In 2024, there is no agreed calculation method for mass balance approach in EU plastic sector (EC & Eunomia, 2022), which is why European chemical recyclers called for urgent decision on calculation and allocation rules (Plastics Europe, 2023a). Allocation rules are necessary to link inputs, such as plastic waste, with multiple outputs—including plastics, chemicals, and fuels—generated through the chemical recycling process. In Europe, three primary allocation methods are being debated for long-loop chemical recycling (pyrolysis and gasification): a) proportional allocation, b) polymers-only, and c) fuel-exempt method. Proportional allocation requires that recycled content is distributed across all output products according to the proportion of different types of input and recycled content claims cannot be transferred from one output product to another. In the polymers-only allocation method, recycled inputs can be assigned flexibly across polymer outputs. In the fuel-exempt method, fuel outputs are not considered recycled materials and are

omitted from mass balance calculations, allowing the remaining theoretical recycled content to be freely distributed among the other outputs. In contrast to the proportional allocation method, it offers the highest allocation freedom and the lowest transparency (Warringa et al., 2023).

The accounting of recycled content is complex in practice. While the rolling average percentage method is considered more credible, as it more accurately reflects actual outputs, its application is limited due to the small amount of input by most operators. The credit method allows producers to sell recycled-content material up to the amount of recycled input that has been introduced into the process (adjusted for process losses), however, credit transfer restrictions, including geographical limitations in credit transfer, need to be considered (EC & Eunomia, 2022).

Advantages of the mass balance approach. When does it work best?

There are several reasons why the mass balance approach would be a preferred or only option for claiming sustainable content, as outlined below:

- **Mass balance is applicable when ingredients are mixed and cannot be physically separated**; such as in pyrolysis and gasification in the chemical industry. Chemical recycling allows for the recycling of plastics that cannot be processed by mechanical recycling—such as hard-to-recycle plastic products. To enable chemical recyclers to claim and verify the use of sustainable content and help increase recycling rates, the mass balance approach is essential (CEFIC, 2023). There is however a need for harmonized calculation rules for recycled content using the mass balance approach (Plastics Europe, 2023a).
- **Mass balance can be advantageous when sustainable feedstock availability is low**. In emerging industries where feedstock availability, technology, or infrastructure is insufficient to support chain of custody models based on physical segregation, the mass balance approach can be utilized (Mononen, 2023).
- **It allows using existing infrastructure.** Since the mass balance model relies on calculations and bookkeeping rather than physical segregation, it can enable the use of existing infrastructure which spares costly investments. This can motivate large-scale existing operations to integrate sustainable feedstock and thus enable them to foster more sustainable operations (Mononen, 2023).

Downsides of the mass balance approach

While mass balance offers flexibility and scalability, it also has certain drawbacks, including:

- **Limited physical traceability and credibility.** As illustrated in Figure 2, mass balance has lower credibility compared to controlled blending and segregation. Since sustainable and conventional inputs are mixed during processing, it becomes difficult to verify the actual share of sustainable content in the final product (Mononen, 2023).
- **Risk of greenwashing.** Some organizations caution that if mass balance rules are not strictly defined, the approach could be misused for greenwashing. Companies might claim and market products as being made from recycled materials regardless of their actual composition. This could lead to reduced incentives to improve recyclability, hinder efforts to increase recycled content in products, and undermine trust in the recycling industry (Tabrizi et al., 2021). In chemical recycling, where mass balance plays a crucial role, proportional allocation is considered the most transparent approach. This is why some industries and NGOs support its adoption (EuRIC 2023, ZWE 2023). They caution that the fuel-exempt method, currently promoted by the chemical industry due to its flexibility (Plastics Europe, 2023a), could be used as a loophole for greenwashing (ZWE, 2023).
- **Clear labeling would be needed to avoid misleading claims.** Plastics Europe emphasizes the need for clear labeling to differentiate between products attributed through mass balance and those made via fully segregated production. To prevent misleading impressions about the actual recycled or bio-based content, they recommend using terms like "recycled-attributed" or "bio-attributed" instead of simply "recycled" or "bio-based" (Plastics Europe, 2023b). For the label to be effective, however, consumers would have to understand the meaning of sustainable content attribution.

Mass balance and certification

To enhance the traceability of plastics recycling and recycled plastic content, third-party certification plays a crucial role. For controlled blending, certification schemes may follow the EN 15343 European standard. RecyClass is an example of a certification scheme based on controlled blending and includes members from well-known brands such as Unilever, P&G, PepsiCo, Danone, L'Oréal, Kao, Henkel, and Mondelez, among others (RecyClass, 2025). For mass balance, while voluntary, several certification programs exist, which

include ISCC Plus, RSB Advanced Products Scheme, REDcert, PSV, QA-CER, RAL Quality mark, and EcoLoop, among others (EC & Eunomia 2022, Mononen 2023).

A key challenge of mass balance certification schemes however is the variation of their methodologies (Mononen, 2023). Although certified schemes undergo annual third-party audits, differing requirements across programs make result comparisons difficult, potentially undermining trust in sustainability claims. The certification systems differ for example in mass balance level, attributes, credit transfers, and calculation period (Mononen, 2023).

Case study: Ensuring traceability and compliance in Europe: case of plastic bottles

The majority of recycled content claims in EU are related to either segregation or controlled blending (EC & Eunomia, 2022).

Since 2025, EU Member states must include a minimum of 25 % of post-consumer recycled plastic in their PET bottles placed on the market. To monitor compliance with this requirement, a reporting mechanism has been established. Recyclers are responsible for providing declarations of compliance to the manufacturing chain, including economic operators placing bottles on the market. These operators must then calculate and report both the weight and percentage of recycled content used (Decision 2023/2683, 2023). Member States are responsible for collecting this data and submitting it to the Commission (Decision 2023/2683, 2023).

Regulation 2022/1616 (2022) specifies rules for recycled plastic materials intended for food contact and provides a declaration of compliance form for ensuring traceability and proper use.

For recyclers, this declaration serves to verify the identity of the recycler, confirm the recycled origin and recycled content of the plastic, and provide necessary instructions for its use by converters and final users, including labeling. Converters must, among others, disclose product identification, the recycled plastic's origin, the recycled content, additives, and relevant user instructions.

Currently, the EU recognizes only mechanical recycling of post-consumer PET waste as a suitable method to obtain recycled plastic for beverage bottles. However, there are plans to amend Decision 2023/2683 (2023) to establish a methodology for calculating, verifying, and reporting recycled plastic content in beverage bottles based on specific chain of custody models. Controlled blending, which allows the inclusion of non-mechanically recycled PET, is being considered as one such models. Additionally, the mass balance approach may be introduced as an acceptable chain of custody model to account for plastic in non-PET bottles derived from feedstock recycling (Decision 2023/2683, 2023).

Analysis

The mass balance approach is a crucial tool for industries striving for sustainability throughout the value chain. In the plastics sector, it plays a significant role in enhancing recycling rates and facilitating the transition to sustainable materials. However, for the mass balance approach to develop and expand, several key conditions must be met, as outlined below.

- Harmonization and standardization of methods: Harmonizing the certification and verification methods along with establishing clear mass balance accounting and allocation rules for chemical recycling is critical. Appropriate labeling also needs to be decided and standardized.
- Regulatory alignment: Regulatory alignment is important for ensuring consistency and compliance with EU policies and strategies.
- Transparency and credibility: Whether for chemically or mechanically recycled content, adopting transparent and credible certification schemes is essential. Blockchain technology and digital product passports can play an important role in enhancing traceability and strengthening trust in the mass balance approach.
- Establishing trust among the stakeholders: Building trust among stakeholders is essential, particularly in addressing the concerns about transparency and greenwashing. Independent verification, third-party audits, and clear, accurate reporting of sustainable content are key to ensuring credibility. Correct and honest labeling further helps establish confidence among consumers and other stakeholders.
- Respecting priorities: Where physical segregation is possible, and where higher yields and higher qualities can be achieved, mechanical recycling and more credible chain-of-custody models should be prioritized to ensure favorable outcomes, greater traceability, and transparency.

CONCLUSION

This paper outlined the main chain-of-custody approaches commonly applied in the plastics sector – segregation, controlled blending, and the mass balance approach. It further examined relevance and applications of mass balance, as well as its advantages and limitations. Among the three selected chain-of-custody approaches, the mass balance method is characterized by the lowest level of physical traceability and credibility. It is therefore recommended only in cases where physical segregation is not feasible, such as in chemical recycling processes like pyrolysis and gasification. For chemical recycling companies to make credible use of the mass balance approach and gain stakeholder trust, a robust regulatory framework, harmonized certification methods, and clearly defined mass balance accounting and allocation rules are essential.

REFERENCES

1. Caro, D., Albizzati, P.F., Cristobal Garcia J., Saputra Lase I., et al. (2023). Towards a better definition and calculation of recycling. Publications Office of the European Union. https://publications.jrc.ec.europa.eu/repository/handle/JRC131531
2. CEFIC. (2023) European Chemical Industry Council. Chemical Recycling: Delivering recycled content to meet the EU's circular economy ambitions – the Single use plastics directive implementing act and the Packaging and packaging waste directive revision. https://cefic.org/app/uploads/2022/04/Cefic-position-paper-on-Chemical-Recycling.pdf
3. Council Decision 2020/2053. (2020) Council decision (EU, Euratom) 2020/2053 of 14 December 2020 on the system of own resources of the European Union and repealing Decision 2014/335/EU, Euratom. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32020D2053
4. Decision 2023/2683. (2023). Commission implementing decision (EU) 2023/2683 of 30 November 2023 laying down rules for the application of Directive (EU) 2019/904 of the European Parliament and of the Council as regards the calculation, verification and reporting of data on recycled plastic content in single-use plastic beverage bottles. https://op.europa.eu/en/publication-detail/-/publication/d218e54d-8fea-11ee-8aa6-01aa75ed71a1/language-en
5. Directive 2023/2413. (2023). Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=OJ:L_202302413
6. Directive 2019/904. (2019). Directive (EU) 2019/904 of the European parliament and of the council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment, 2019. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32019L0904
7. Directive 2022/2464. (2022). Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting, 2022. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464
8. EC. (2018). European Commission. Communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions. A European strategy for plastics in a circular economy. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018DC0028
9. EP News. (2024). European Parliament news. Deal on new rules for more sustainable packaging in the EU. https://www.europarl.europa.eu/news/en/press-room/20240301IPR18595/deal-on-new-rules-for-more-sustainable-packaging-in-the-eu
10. EuRIC. (2023). European recyclers' stance on chemical recycling, mass balance, and the true essentials to fuel EU circular economy. https://euric.org/images/EuRIC_Position_Chemical_Recycling.pdf
11. Green Claims. (2025). European Commission. https://environment.ec.europa.eu/topics/circular-economy/green-claims_en
12. EC & Eunomia. (2022). European Commission: Directorate-General for Environment, Eunomia, Hann, S., Bapasola, A., Fletcher, E. et al., Study to develop options for rules on recycled plastic content for the implementing act related to single-use plastic bottles under Directive (EU) 2019/904, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2779/13133
13. Lase, I.S. Tonini, D., Caro, D., Albizzati, P.F. et al. (2023). How much can chemical recycling contribute to plastic waste recycling in Europe? An assessment using material flow analysis modeling. Resources, Conservation & Recycling 192, 106916.
14. Mononen, K. (2023). Comparison of chain of custody models in plastic products' green transition. Case: Borealis Polymers Oy. Lappeenranta–Lahti University of Technology LUT. Master's Programme in Circular Economy, Master's thesis.
15. ISCC. (2025). International sustainability and carbon certification. The mass balance approach. https://www.iscc-system.org/certification/chain-of-custody/mass-balance/
16. ISO. (2020). ISO 22095:2020, International Organization for Standardization. Chain of custody — General terminology and models, 2020. https://www.iso.org/obp/ui/en/#iso:std:iso:22095:ed-1:v1:en
17. Plastics Europe. (2019). The circular economy for plastics – A European overview. http s://plasticseurope.org/fr/knowledge-hub/the-circular-economy-for-plastics-a-eur opean-overview/
18. Plastics Europe. (2023a). Cross sectoral statement on the policy framework needed to deliver recycled content in key plastics applications. https://plasticseurope.org/media/sectoral-statement-measuring-recycled-content/
19. Plastics Europe. (2023b). Plastics Europe views on claims made on products using mass balance. https://plasticseurope.org/knowledge-hub/plastics-europe-views-on-claims-made-on-products-using-mass-balance/

20. Rainforest Alliance. (2023). What is mass balance sourcing? https://www.rainforest-alliance.org/business/certification/what-is-mass-balance-sourcing/
21. RecyClass. (2025). Use of recycled plastic. Certification scheme recognising the use of recycled plastics in products throughout the plastics value chain. https://recyclass.eu/recycled-plastic/use-of-recycled-plastic/
22. Regulation 2024/1781. (2024). 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/eli/reg/2024/1781/oj/eng
23. Regulation 2022/1616. (2022). Commission regulation (EU) 2022/1616 of 15 September 2022 on recycled plastic materials and articles intended to come into contact with foods, and repealing Regulation (EC) No 282/2008. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32022R1616
24. Tabrizi, S., Crêpy, M., Rateau, F. (2021). Recycled content in plastics The mass balance approach. Determining recycled content with the 'mass balance approach'. 10 recommendations for development of methods and standards.
25. Warringa, G., Bergsma, G., Bouwman, P., Broerenet M. (2023). Impacts of allocation rules on chemical recycling. Consequences on the environment and maximum circularity of plastics. CE Delft, Delft. https://zerowasteeurope.eu/wp-content/uploads/2023/05/CE_Delft_230135_Impacts_of_allocation_rules_on_chemical_recycling_Def.pdf
26. ZWE. (2023). Zero Waste Europe. New ZWE study proves proportional allocation of recycled content in plastics as the best option to secure a level-playing field and environmental benefits. https://zerowasteeurope.eu/press-release/new-zwe-study-proves-proportional-allocation-of-recycled-content-in-plastics-as-the-best-option-to-secure-a-level-playing-field-and-environmental-benefits/