Feedback on new rules for the recycling of plastic packaging

Input from the Rethink Plastic Alliance to the Call for Evidence on plastic recycling requirements under Article 7 paragraphs (8), (9) and (10) of the Packaging Packaging Waste Regulation (PPWR)

September 2026

About the Rethink Plastic Alliance

The Rethink Plastic Alliance is a coalition of leading European NGOs advocating for ambitious EU policies to tackle the growing crisis of plastic pollution. It brings together the Center for International Environmental Law (CIEL), ClientEarth, the Environmental Investigation Agency (EIA), the European Environment Bureau (EEB), the European Environmental Citizen's Organisation for Standardisation (ECOS), Greenpeace, Seas At Risk, Surfrider Foundation Europe, and Zero Waste Europe. Together, these organisations represent thousands of active groups, supporters and citizens in every EU member State working towards a future free from plastic pollution.

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Summary

Implementing the PPWR requirements on minimum recycled content in plastic packaging now depends on the development of robust and reliable secondary legislation on **(1)** the calculation and verification of recycled plastic content in packaging, **(2)** sustainability criteria for plastic recycling technologies, and **(3)** equivalent rules for plastic recycled content that is imported from third countries.

1. For calculating and verifying recycled plastic content, **the EU should move away from "credit" mass balance systems that decouple reporting from physical reality.** This means prioritising segregation and controlled blending models, and allowing only rolling average mass balance at site level. System boundaries should be fully accounted for, starting from the plastic waste stage down to plastic recyclate to capture all pre- and post-treatment steps. Lessons should also be learned from the flaws in the SUPD method, such as the reference standard methods and the dual-use output concept, as shown in a recent JRC study on recycled content for critical raw materials in batteries.

   Regarding environmental performance, the precautionary principle requires full disclosure of hazardous substances throughout the supply chain to prevent unsafe materials from being certified as recycled content and avoid contamination. As for economic performance, pyrolysis remains technically stagnant, expensive, and prone to project failures. It is also more a chemical recovery process than a real recycling process. More generally, the risks of locking-in fossil fuel use should be assessed for each recycling technology.

2. **The sustainability criteria under the PPWR should apply the Do No Significant Harm (DNSH) principle** across seven un-aggregated areas: carbon footprint (via Product Environmental Footprint/PEF without credit mass balance), human toxicity, energy use, water use/pollution, localized pollution, biodiversity, and fossil resource use. They should follow the hierarchy of Mechanical Recycling → Solvent-Based Stripping → Chemical Recycling, reflecting the thermodynamic realities. The criteria should also assess the full process steps rather than isolated reactions, including pre- and post-treatment steps. They should thus require full disclosure of chemicals and solvent processing impacts, including their impacts on human toxicity and freshwater ecotoxicity, to ensure a comprehensive environmental assessment.

3. **The EU implementing act for assessing, verifying and certifying equivalence should strictly align the definition of recycling with EU legislation** by excluding fuel, and ensuring imported post-consumer recycled plastic meets identical recycling, environmental, and non-fuel processing criteria. The equivalent rules should also be based on plant-level mass balance at the level of the manufacturing plant and credit allocation equitably distributed per economic area to ensure a level-playing field between operators, especially European SMEs. Last but not least, the methodology should incorporate the waste management safeguards from the EU Waste Shipment Regulation to ensure coherence among EU legislation.

PPWR Article 7(8): Mass Balance Discussion

Apply the principles of proportionality, effectiveness and precaution to ensure a better alignment of the European legislative framework

As it currently stands, companies can claim “recycled content” for material that does not physically contain recycled content material, due to the official recognition of a credit mass balance system in the recently adopted Implementing Decision of the Single Use Plastics Directive (EU) 2026/1425. This is wrong, and the upcoming Implementing Act has the opportunity to end this practice and support genuine circularity for the plastics packaging sector.

Applying the rolling average mass balance - or proportionality principle - would ensure that circularity effectively happens within the packaging sector as it would help meet the objectives of the EU Regulation.[1] The PPWR notably addresses packaging circularity by increasing the uptake of recycled plastics through mandatory targets for recycled plastic content.[2] This objective can only be met if companies can account for recycled plastic content based on a methodology that enables physical and chemical tracking and verification of the material. If the methodology is based on a credit mass balance system that decouples their reports from reality, they do not reflect the actual amount of recycled plastic content present in the materials used for the packaging. Such a system creates the appearance of circularity without its substance, and cannot therefore be considered a proportionate way of meeting the targets.

Additionally, the principle of effectiveness should be established as a core principle of the upcoming Implementing Act to ensure that the objectives of the PPWR are met, namely, that packaging circularity increases and the amount of packaging waste is reduced. In line with this principle, recycled plastic content should be strictly limited to post-consumer waste, in accordance with the decision defined by the CJEU.[3] Furthermore, the emphasis on post-consumer plastic waste creates an additional incentive to work towards achieving the separate collection targets which are also contained in the PPWR.

Enhancing both traceability and transparency along the value chain enables the practical application of both the proportionality and effectiveness principles. Recycled content targets under the PPWR currently concern plastics by creating a market pull for secondary raw material. However, plastic waste is chemically complex: of the roughly 16,325 substances associated with plastics, an estimated 4,200 are considered harmful.[4] During recycling, these harmful substances can remain in the process in two ways: either by persisting within the recovery operation, or by forming new substances through their interactions enhanced by the recovery process itself.[5] Therefore, as it stands for plastics, recycling cannot reliably control the presence of hazardous substances or contamination in its outputs. **In the absence of robust testing, any accounting**

[1] Treaty of the European Union, Article 5 (4): “Under the principle of proportionality, the content and form of Union action shall not exceed what is necessary to achieve the objectives of the Treaties.”

[2] PPWR, recital (36).

[3] CJEU, Case C-434/97, Commission v France, para. 21

[4] Monclús, L. et al., Mapping the chemical complexity of plastics, 2025

[5] Qian, K.; Tian, W.; Li, W.; Wu, S.; Chen, D.; Feng, Y. Catalytic Pyrolysis of Waste Plastics over Industrial Organic Solid-Waste-Derived Activated Carbon: Impacts of Activation Agents, 2022

system risks certifying "recycled plastic content" that could carry safety risks and undermine trust in recycled materials. The precautionary principle thus requires data on chemicals potentially hazardous to human health or the environment - including the chemical composition of recycled materials - to be disclosed and passed on throughout the supply chain supported by the development of the Digital Product Passport (DPP).[6]

Lastly, the definitions introduced under the SUPD Implementing Decision (EU) 2026/1425[7] should be removed or at least corrected to ensure that the overall legislative framework remains coherent and enforceable. Two definitions in particular require attention:

1. **The definition of "chemical building blocks" should be replaced with the legally defined term of "intermediates"**: Under the REACH Regulation, an "intermediate" is "a substance manufactured for, and consumed in, a chemical process to be transformed into another substance." Such a definition effectively reflects the process that is happening to waste being transformed into recovery materials, and should apply consistently to any intermediate arising from any process. Using the technically accurate term "intermediate", rather than the marketing concept "chemical building blocks", would improve scientific precision in describing substances undergoing changes during a chemical process as it is the case during any recovery operation, ensure regulatory alignment with chemical legislation, and clarify the scope and transitional nature of the substances within this process.

2. **The "dual-use output" concept is incompatible with the definition of recycling**: Article 3(17) of the Waste Framework Directive (WFD) defines recycling as a "recovery operation in which waste materials are effectively reprocessed into products, materials, or substances." However, "dual-use output" does not guarantee this effectiveness. Indeed it is defined as "outputs other than losses that can be reprocessed either into fuels or materials other than fuels" effectively. In other words, it means that "dual-use" applies to intermediates which may either be transformed into non-fuels products or into fuels. This practice is explicitly excluded from the EU definition of recycling.[8] It will thus represent an unfair competitive advantage for economic operators applying such a method.

Reconsider allocation rules, chains of custody and system boundaries

When accounting for recycled materials, different chains of custody are available, offering different levels of traceability and transparency along the value chain. **It is essential to prioritise the models that enable the highest level of traceability and physical integrity**.[9] Segregation and controlled blending should therefore be preferred over mass balance systems. These processes either enable

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[6] ZWE, Building a healthy circular economy: Integrating chemicals, products, and waste under the Circular Economy Act, 2026

[7] Commission Implementing Decision (EU) 2026/1425 laying down rules for the application of Directive (EU) 2019/904 as regards the calculation, verification and reporting of data on recycled plastic content in single-use plastic beverage bottles

[8] Waste Framework Directive 2008/98/EC, Article 3(17): "It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations"

[9] Eunomia, A Comparative Assessment of Standards and Certification Schemes for Verifying Recycled Content in Plastic Products, 2021

recycled and virgin material to be physically distinct (segregation) or tightly controlled in known, verifiable proportions (controlled blending). Both are in line with Regulation 2022/1616.[10]

In the case where the mass balance system cannot be avoided, it should be defined precisely according to the following requirements: **rolling average percentage mass balance at the batch-level, which is the only approach preserving physical and chemical traceability that allow for reliable and transparent environmental reporting and claims.** The rolling average percentage method is also the only mass balance implementation method ensuring a level playing field between different recycling technologies, preventing the undermining of the European recycling landscape. Indeed, the dilution factor is the same for all technologies, enabling a proper comparison between recycling technologies based on their capacity to keep plastic materials in the loop. Unfortunately, the mass balance attribution rules of the SUPD Implementing Decision severely undermine the objective of fostering circularity in plastics by giving the impression that changes are happening, while it is not the case in reality. It should also be noted that **the "fuel-use excluded" approach is the least environmentally ambitious option available to European legislators.** In addition, the dual-use concept further expands the system boundaries of the "fuel-use excluded" rule, allowing the reporting of figures that represent even less the physical flows of recycled content material. As a result, it challenges compliance with the definition of recycling, as explained above. To apply the concept of "dual-use output", the SUPD Implementing Decision sets a system based on gas chromatography working with "maximum acceptable boiling point", a standard test method for the boiling range distribution of petroleum fractions. But critically, this method is highly subjective to interpretation and particularly unreliable for pyrolysis oil, whose composition differs from virgin naphtha.[11] The four following points show this approach cannot be relied on and will not help identify the individual components from pyrolysis oil that subsequently go on to making recycled plastic:

1. **One single sample cannot capture real world variations:** pyrolysis oil quality varies greatly from batch to batch, depending on the waste input at the start of the process. This cannot be standardised since it depends entirely on what has been collected. Yet, the standard test relies on a gas chromatography sample of roughly 5 grams to characterise many tonnes of oil. Such a sample cannot represent the variety of pyrolysis oil produced, which directly impacts the result of the gas chromatography and the subsequent determination of the proportion of dual-use output that go either into the non-fuel product or the fuel product.[12]

2. **Pyrolysis oil from plastic waste is not a standard oil**: the examples from the referenced standard rely on the light fractions of crude oil. Economic operators can use it as a reference to estimate the nearest likely component, but pyrolysis oil is completely different from naphtha in its hydrocarbon composition. This leaves even more scope for

[10] 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 (Text with EEA relevance)

[11] Rollinson A, PhD, Leaky loop "recycling": A technical correction on the quality of pyrolysis oil made from plastic waste, 2023

[12] Erkmen, B.; Ozdogan, A.; Ezdesir, A.; Celik, G. Can Pyrolysis Oil Be Used as a Feedstock to Close the Gap in the Circular Economy of Polyolefins?, 2023

inconsistency and misrepresentation of the peak areas of pyrolysis oil, hence the weight of the hydrocarbons.[13]

3. **Testing frequency is not defined:** there is no requirement specifying how often testing must be conducted. As outlined in point 1, the composition of pyrolysis oil differs at each batch depending on the input waste composition and the process used, therefore variability of test results can be significant between operators.

4. **System boundaries are too narrow:** as designed in the SUPD Implementing Decision, the system excludes major relevant upstream and downstream steps. Without extending the boundaries to cover these steps, the accounting system captures only a partial slice of the value chain, leaving room for hydrocarbon content and mass balance calculations to be distorted in the steps outside the boundaries.

To properly capture all losses occurring at each stage of the process, **the first calculation point should be set at the very beginning of the process**, meaning at the plastic waste stage. In the case of pyrolysis, this means before the waste enters the pyrolysis plant. Such extension makes it possible to account for treatments necessary for pyrolysis oil to meet steam cracker requirements, such as hydro-treatment and hydrocracking and the additional treatments needed to bring "dual-use output" back into circulation. This broader boundary also highlights the need for further purification. Indeed, recovered pyrolysis oil is typically too contaminated, or otherwise fails to meet the requirements set for steam crackers requirements designed around virgin petroleum naphtha.[14] To remove these contaminants, especially for the high purity needed for substances or monomers used in contact-sensitive plastic applications, multiple stages of energy-intensive treatment are required. Given this, the main alternative is to dilute plastic-derived pyrolysis oil with virgin petroleum naphtha. It is generally assumed that blending 5–20% pyrolysis oil with 80–95% virgin petroleum naphtha is what would be needed to sufficiently counter contamination.[15] On this basis, the maximum achievable recycled plastic waste content in new plastic would be just 0.03%.[16]

Beyond the dilution problem, the gas chromatography analysis itself introduces a further layer of uncertainty: the results are subjective to the person interpreting the chromatography, reinforcing the already creative and deceptive nature of the mass balance accounting system. **As the use of credit mass balance attribution spreads, so does the risk of greenwashing claims on recycled content.** This is not simply a hypothesis; various institutions have already identified it as a real issue. For example, the Environmental Protection Agency in the US addressed it directly in its Safer Choice Standards. The same can be seen in the textile sector, when the Dutch Authority for

[13] Annex A of EN 15199-4, Petroleum products - Determination of boiling range distribution by gas chromatography method - Part 4: Light fractions of crude oil

[14] Rollinson A, PhD, Leaky loop "recycling": A technical correction on the quality of pyrolysis oil made from plastic waste, 2023

[15] Kusenberg et al. (p. 107) point to 5-20% as the expected range for industrial co-feeding (likely industrial scenario). It acknowledges dilution would only be sufficient for a few contaminants, while most would still require further treatment such as hydrotreatment

Kusenberg et al. (2024, p. 1) test a blend of 20% pyrolysis oil and 80% naphtha and finds that oxygen-related contamination is a problem and further upgrading is needed (5% blend not tested)

Gracida-Alvarez et al. (p. 3) model 5% and 20% co-feeding scenarios and assume 5% can be co-fed without purification because contaminants are sufficiently diluted, whereas 20% requires prior purification

[16] Rollinson A, PhD, 'Dual-use output' issues for accounting recycled plastic content, 2024

Consumers and Markets criticised H&M and Decathlon for their misleading claims, but also in the UK, as shown by the recent investigation from the Advertising Standards Authority.

While several elements of the SUPD Implementing Decision should be amended, it is important to recognise the two safeguards that should remain within the upcoming PPWR Implementing Act:

1. **Positive balance of recycled plastic content may be carried over to the next accounting period:** the company should ensure a zero or positive balance within the mass balance period at the recycling plant level and continuously account for all outputs produced in the same plant.[17]

2. **Attribution rules, if used, should remain within one facility**, blocking the possibility for cross-site or cross-company transfer: such a requirement favours the development of recycling through the entire Union and delivers on the proximity principle, which is at the core of the EU waste legislation. In other words, waste should be treated where it is produced.

Assess true economic performance considering limited technical developments and integrated costs

Technical development of chemical recycling (pyrolysis) has been stagnant since the 1970s. Chemical recycling projects have experienced nothing but "delays, barriers, cost overruns, and pollution" in the US.[18] They process "insignificant amounts of plastic waste" and "mostly produce low-quality fossil fuels for burning." Chemical recycling is also expensive and risky considering the large number of failed projects worldwide.[19]

Economic performance should factor in the low price of virgin plastics that are artificially cheap largely because of free allocation in the Emissions Trading System (ETS), and non-inclusion in the Carbon Border Adjustment Mechanism (CBAM); hence virgin plastic does not carry its true cost. The environmental impacts of primary plastic production is almost entirely absent from the price of virgin plastic. The GHG emissions, extraction of new fossil resources, and both direct and indirect pollution associated with the primary production are treated as free by the market, while recyclers absorb the real costs of collection, sorting, and processing plastic waste. This situation creates an important price gap between virgin and recycled plastics that won't change no matter how much recycling capacity is built in Europe.

Additionally, demand for recycled plastics is increasingly met by imports from outside the Union as shown by the recent data that 19% of converter demand for recycled plastics in Europe is currently met through imports, with 12.4% of Europe's own collected waste being recycled in other regions rather than domestically. A reason for the price difference between European and non-European recyclates lies in the lower price due to lower - or the complete absence of - environmental or

[17] JRC study on harmonised rules for the calculation and verification of recycled content in batteries – JRC recommendations to support the provisions of Article 8 of Regulation (EU) 2023/1542, 2026
[18] Bell, L. 2023. Chemical recycling: a dangerous deception. 2023. Beyond Plastics and International Pollutants Elimination Network
[19] In the US: Bell, L. 2023
In Indonesia: Aliño, M., Moon, D., Tangri, N. (Eds.). 2022. Chemical recycling of sachet waste: a failed experiment. Global Alliance for Incinerator Alternatives

labour standards. Therefore, the need to develop the equivalent rules as part of secondary legislation is key and should be enforceable.

Besides, the economic performance assessment should evaluate whether the recycling process relies on incentives or perpetuates fossil-fuel feedstocks and energy systems, leading to a fossil fuel use lock-in. This should especially consider the virgin fossil fuels needed as co-feedstocks, chemical reagents or high-temperature energy inputs. It should also assess whether the capital expenditure (CapEx) locks municipal or industrial assets into multi-decade operation cycles that mandate a steady volume of fossil fuel to remain economically viable, and if returns are artificially inflated by fossil subsidies or carbon offset credits.

PPWR Article 7(9): Sustainability Criteria

Set ambitious and comprehensive sustainability criteria

The Commission should set **comprehensive sustainability criteria assessing impacts of plastic recycling technologies on the climate, environment and human health** to ensure the necessary safeguards "in particular with regard to the level of emissions into the air, water and soil, and to resource efficiency"[20] and "the way in which recycled content is obtained [to make sure it] does not cancel out the environmental benefits of using such recycled content in subsequent plastic packaging."[21] To do so, it should assess **all of the following criteria** to avoid trade-offs and indirect effects, in line with the "do no significant harm" (DNSH) principle:

1. **Carbon footprint**: using a transparent and non-discriminatory life cycle assessment (LCA) method established by the EU, based on the EU Product Environmental Footprint (PEF) method. This method should account for the full life-cycle and recycling process stages of the relevant plastic recycling technologies (see next section).

2. **Human toxicity:** considering the potential impacts on human health caused either by absorbing substances from the air, water and soil, or by increased toxicity in the recycled products compared to the new ones as a result of the added additives during the recycling process.

3. **Energy use:** measured at each step of the recycling process, considering the full life cycle.

4. **Water use and and releases into water:** assessing the water-related impacts, including from emissions of plastic fragments, microplastics or substances of concern contained in plastics, during all life cycle stages, and the resources needed to clean water, such as from solvents.

5. **Pollution**: considering the pollution impacts into air, water and soil during installation, operation and decommissioning of recycling facilities.

[20] PPWR, recital (48)
[21] PPWR, recital (45)

6. **Biodiversity and ecosystem protection and restoration:** assessing whether recycling processes lead to the disturbance, capturing or killing of legally protected species or the deterioration of legally protected habitats.

7. **Resource use, especially fossil resources:** based on the amount of materials contributing to resource use, fossil fuels are converted into MJ.

Applying the DNSH principle will help ensure the environmental integrity of the classification of recycling technologies. For this purpose, these criteria should be assessed and not aggregated.

In addition, the LCA method should not allow the use of commodity certificates relying on credit mass balance or book & claim, as prescribed by the PEF method[22]. This will help accurately measure **climate, environment and human health** impacts by matching the administrative and physical flows. If possible, direct measurement should be favoured.

Consider environmental impacts throughout the recycling process steps

Consider full system boundaries

When assessing the environmental impact of plastics recycling, the sustainability requirements under Article 7(9) should consider full system boundaries **including all pre- and post-processing steps needed to obtain final plastics pellets, flakes or powders**. Only then can we ensure proper comparison between different technological processes. For post-processing, this means considering the treatment of residues or waste, the impacts of hydrogen production, as well as distillation, steam cracking, hydro-processing, and polymerisation for pyrolysis[23].

Factor in pre- and post-treatment steps

In addition, particular attention should be given to parts of the process that generate the most emissions, waste and ultimately costs. Following the law of physics, the higher the recovery process goes up along the value chain, the more energy and resources are needed to bring it back into use. No technological maturity or investment can change this as it is simply a matter of thermodynamics. **This implies the sustainability criteria should consider the following plastics recycling hierarchy: mechanical recycling → solvent-based stripping → chemical recycling.**[24]

Moreover, chemical recycling needs proper plastic waste sorting and pre-treatment.[25] The sustainability criteria should require **disclosing the type of pre-treatment applied, the techniques and their environmental impacts**, including energy, resources and losses (waste generation and safe disposal).[26] This is the case for washing and drying steps, potentially homogenisation and

[22] ECOS. Recommendations on using mass balance in the Product Environmental Footprint method. 2025
[23] Rollinson, A.N., for RPA, ECOS, ZWE. 'Scrutinising scientific standards: A Scientific Assessment of the JRC Study on European Sustainability Criteria for Plastics Recycling Technologies'. 2025
[24] 'Solvent-based stripping' is sometimes called 'physical recycling', but it is confusing. Rollinson, A.N., 2025
[25] García-Gutíerrez, P., Amedei, A.M., Klenert, D., Nessi, S., Tonini, D., Tosches, D., Ardente, F., Saveyn, H.G.M. 2025. Environmental and economic assessment of plastic waste recycling and energy recovery pathways in the EU, Resources, Conservation & Recycling, 215, 108099
[26] Rollinson, A.N., 2025

shredding. For microwave-assisted pyrolysis, mixing of the feedstock with catalyst or other wave absorbing media is needed.[27]

Require reporting transparency for a comprehensive environmental assessment

Usually, the parts related to **the reagents, the solvents, the purification and decontamination stages** are not included in environmental assessments. However, for sustainability criteria to deliver both on a clear environmental impact framework and economic impact, these elements should be considered. This includes:: solvent volume, pH adjusting chemicals and their processing (flared or recovered), hydrogen for hydro-cracking of pyrolysis oil, the catalysts used in the processes, and the GHG emissions for steam cracking.[28]

In the case of PET depolymerisation by a solvent, the fate of the solvent is usually not mentioned (see further info on PET depolymerisation in the annex). It is unknown what happens to the solvent used for the process to run; how much is regenerated, how much energy that regeneration requires, how much solvent carries over into the recycled output, and where plastic additives end up are all important elements that are left aside.

The sustainability criteria should require full disclosure of chemicals and solvent processing impacts. This should include their **impacts on human toxicity (cancer and non-cancer) as well as freshwater ecotoxicity**. This is also essential for solvent-based stripping, which shows high toxicity scores associated with waste disposal of all the solvents and other reagents this technology uses.[29]

In the case of successful recovery by pyrolysis, the reaction rarely produces a “clean” monomer or other chemical compound. Instead, it usually produces a complicated mixture of unwanted chemicals, including plastic additives, which requires extensive purification (and polymerisation) before it can go anywhere near a plastics production line. Therefore, the sustainability criteria should require a **full disclosure of purification and upgrading steps** until the materials are transformed into pellets, powders or flakes, rather than just the initial breakdown, as this is where the real environmental impact is and what reduces the economic viability of recycling. This is especially true for pyrolysis, which produces a residual oil so contaminated[30] that it needs intermediate upgrading steps and must be heavily diluted with virgin crude oil and treated with significant effort before it can enter material processing facilities. The environmental impacts of virgin naphtha should thus be factored in when the oil is diluted.

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[27] Rollinson, A.N., Oladejo, J.M. 2019. ‘Patented blunderings’, efficiency awareness, and self-sustainability claims in the pyrolysis energy from waste sector. Resources, Conservation and Recycling, 141, pp. 233-242

[28] Rollinson, A.N., 2025

[29] Uekert, T., Singh, A., DesVeaux, J.S., Ghosh, T., Bhatt, A., Yadav, G., Afzal, S., Walzberg, J., Knauer, K.M., Nicholson, S.R., Beckham, G.T., Carpenter, A.C. 2023. Technical, economic, and environmental comparison of closed-loop recycling technologies for common plastics. ACS Sustainable Chemistry and Engineering, 11, pp. 965-978

[30] “The pyrolysis of waste plastic produces a large spectrum of aliphatic and aromatic hydrocarbons with different molecular weights, which in most cases, can not be used without further post-treatment. Moreover, plastic waste contains various contaminants, such as halogens, metals and additives, which can be present in pyrolysis products. These contaminants are responsible for many problems, including corrosion, catalyst poisoning and clogging”. Belbessai, S., Azara, A., Abatzoglou, N. 2022. Recent advances in the decontamination and upgrading of waste plastic pyrolysis products: an overview, Processes, 10, 733

Moreover, the sustainability criteria should take into account the **impacts of water use and wastewater generated** for the different recycling technologies. Water use will be high for solvent-based stripping, as well as chemical recycling for water cooling.[31] They are also significant for some post-process purification processes.[32]

Besides, plastic recycling technologies can have significant **impacts on microplastics emissions**. The sustainability criteria should also consider them from a full life cycle perspective.

PPWR Article 7(10): Equivalent Rules

Apply equivalent definitions of recycling

Where the recycled plastic content is recovered from post-consumer plastic waste collected or recycled in a third country, it is first essential to consider the very definition of recycling used. The international ISO definition indeed defines recycling as: "processing of waste materials for the original purpose or for other purposes, excluding energy recovery."[33] It deviates from the EU definition of recycling since waste reprocessing into materials that are to be used as fuels can be counted as recycling. The Implement Act establishing the methodology for assessing, verifying and certifying equivalence should thus clearly exclude such reprocessing.

Restrict recycled content allocation to plant level

When applying credit methods, an unlevel playing field can be created for EU market operators versus operators serving several markets. These latter could indeed allocate the recycled plastic content they sell in third countries without recycled content requirements to the EU market.[34] This benefit would be even bigger if they only sell a small portion of their product in the EU. This option is however not possible for operators focusing only on the EU. This would especially be detrimental to European SMEs. The equivalent rules should thus be based on **plant-level mass balance** at the manufacturing plan level and credit allocation equitably distributed per economic area.[35]

Ensure equivalent waste-management and environmental protection standards

The methodology for assessing, verifying and certifying equivalent waste management and environmental protection standards under Article 7(10) PPWR should be aligned with that already established in Regulation (EU) 2024/1157 on shipments of waste (Waste Shipment Regulation, WSR).[36] The WSR establishes that waste exported from the Union is considered to be managed in

[31] Uekert et al., 2023
[32] Quicker, P. 2023. Status, potentials and risks of chemical recycling of waste plastics. Study on the evaluation of approaches for the feedstock recycling of plastic waste. Federal Office for the Environment: Bern, pp. 1-103
[33] ISO 472:2013, Plastics — Vocabulary, 2.1706.
[34] Option 3c in the JRC study on harmonised rules for the calculation and verification of recycled content in batteries – JRC recommendations to support the provisions of Article 8 of Regulation (EU) 2023/1542, 2026
[35] Option 3d in the JRC study on harmonised rules for the calculation and verification of recycled content in batteries – JRC recommendations to support the provisions of Article 8 of Regulation (EU) 2023/1542, 2026
[36] Regulation (EU) 2024/1157 on shipments of waste

an environmentally sound manner only where it can be demonstrated that the waste (as well as any residual waste generated through its recovery or disposal) will be managed in accordance with human health, climate and environmental protection requirements considered equivalent to those under Union legislation. Equivalence requires the country of destination to ensure a similar level of protection of human health and the environment. Relevant Union legislation and the international guidance listed in Annex IX WSR are to be used as points of reference for that assessment.

The PPWR equivalent rules should apply the same principle to imported recycled plastic content. Recycled content produced from **plastic waste collected or recycled outside the Union should not qualify towards EU recycled-content targets where the underlying waste management and recycling take place under conditions that do not provide a similar level of protection to those required in the Union.**

The WSR also provides a useful framework for determining what such equivalence requires in practice. For example, for exports to third countries it requires exporters to demonstrate that receiving facilities will manage waste in an environmentally sound manner and prohibits exports to facilities that do not meet the criteria in Part B of Annex X. Exporters must ensure that relevant facilities are subject to an independent audit before waste is exported to them.

For plastic waste specifically, the WSR further requires scrutiny of whether third countries have requirements ensuring that plastic waste is **recycled in an environmentally sound manner, whether residual waste from recycling is also managed in an environmentally sound manner, prohibitions on open burning or dumping, whether imports undermine the environmentally sound management of domestically generated plastic waste and whether regular enforcement and inspections** are carried out to mitigate pollution to air, soil, water and the marine environment. These criteria provide an established EU legislative benchmark that should inform the PPWR methodology for determining whether imported recycled plastic has been produced under genuinely equivalent conditions.

The Commission should therefore ensure coherence between the PPWR and the WSR by incorporating **WSR waste management safeguards** into the methodology for assessing, verifying and certifying equivalence under Article 7(10).

Annex: The specific case of PET depolymerisation

Depolymerisation of condensation polymers must be distinguished from depolymerisation of other polymers, notably of addition polymers. While the depolymerisation of the latter is as difficult in practice as in theory, and while it leads to messy mixtures from which monomers can be isolated with difficulty and low yields, (some) condensation polymers can be readily depolymerised, with easy isolation of the monomers and high yields. This is the case for polyethylene terephthalate (PET), the top volume polyester. Some polyamides can also be depolymerised successfully, but this is not the case for epoxy resins, e.g. based on condensation of bisphenol A with an amine.

Depolymerisation of PET is easy because the polymeric chain can only be cleaved at specific points, i.e. the single C-O bond of the ester linkage, following nucleophilic attack, usually by methanolate (the conjugate base of methanol) under basic conditions or by water under acid catalysis. Like ester formation from a carboxylic acid and an alcohol, the reverse reaction (using water) is an equilibrium reaction requiring high temperatures to overcome activation energy, but little overall energy input. The same holds for transesterification, i.e. depolymerisation using methanol.

However, successful removal of at least one of the reaction products is one way to successfully shift the equilibrium reaction towards completion. Conveniently, this is the case for PET: ethylene glycol (197 °C at atmospheric pressure) can be removed by distillation, and so can dimethyl terephthalate (the product from methanolysis) or terephthalic acid (the product from hydrolysis), both of which boil around 300 °C at atmospheric pressure, but at lower temperatures under reduced pressure. Removal and recovery of monomers by distillation yields substances of good purity (and that can be further purified by distillation or crystallisation), even when the reaction mixture contains all kinds of additives (such as pigments or fillers) or impurities (such as other polymers). The reaction mixture, being a solution, can be conveniently kept homogeneous in composition and temperature; however, process variants using methanol in the vapour phase also exist. A convenient review of process variants was published by Pudack *et al*.[37]

It should be noted that depolymerisation of addition polymers - generally done through pyrolysis - offers none of these advantages:

1. No built-in breakage points in a polymer backbone consisting only of C-C single bonds,
2. Chain breakage as a thermally-induced and radical reaction, with homolytic cleavage of C-C bonds, which
    - Generates fragments of random length,
    - Generates reactive fragments that can react with other chain fragments or with additives,
3. Kinetically determined irreversible reaction instead of a thermodynamically driven reversible reaction in the case of polyester depolymerisation. This means that an undesired molecule does not revert to a desired molecule,

[37] Pudack, C., Stepanski, M. and Fässler, P. (2020), PET Recycling – Contributions of Crystallization to Sustainability. Chemie Ingenieur Technik, 92: 452-458. https://doi.org/10.1002/cite.201900085

4. Generally a solid-state (and non-fluidised) reaction instead of solution-phase, leading to difficult thermal and compositional homogenisation, especially when scaling up.
5. Formation of multiple small molecular species, likely with similar boiling points, leading to difficult or impracticable purification by distillation.

In the case of depolymerisation by a solvent, the fate of the solvent is usually not mentioned. It is unknown what happens to the solvent used for the process to run; how much is regenerated, how much energy that regeneration requires, how much solvent carries over into the recycled output, and where plastic additives end up are all important elements that are left aside. This leads to substantial misinterpretations of the cost situation in a recent report by the JRC.[38] In section 5.3 on page 58, the JRC cites two sources: Lux Research (2020), a one-page unreferenced and unreviewed factsheet, and Wood Mackenzie (2022), an unreviewed slide-deck. They are credited as the source for high solvent (i.e. methanol) costs (“>800 USD per tonne of treated plastic”), or that “catalysts and chemicals make up 73% of the total operating cost”, respectively, the latter being a statement of little economic relevance. (It should be noted that the slide deck also gives only relative figures on page 12, but no information on total operating cost.)

These statements should be assessed against the solvent’s fate in the depolymerisation reaction and against the price of methanol. Industrial methanol’s price is linked to gas prices, natural gas being its most important input material. Over the last ten years, it has generally traded around 300 €/t.[39] This means, in conjunction with the statement by Lux Research, that roughly 2.5 tonnes of methanol are used per tonne of treated plastic, i.e. PET. But what happens to the methanol? This methanol has two uses:

1. **Reacting with PET to form DMT**, the monomer that can be used again to polymerise new, chemically recycled PET. Its (maximum) quantity can be determined easily and with precision, based on the relative molecular weights of the different molecular species involved, and on their reaction stoichiometry. This can be calculated as follows:
    - The repeating unit of PET has the formula $C_{10}H_8O_4$, with a molar mass of 192 g/mol.
    - DMT (for the sake of completion), the product taking up methanol after transesterification, has the formula $C_{10}H_{10}O_4$, with a molar mass of 194 g/mol.
    - Methanol, CH_4O, has a molar mass of 32 g/mol.
    - One repeating unit of PET reacts with two molecules of methanol to produce one molecule of DMT.
    - The ratio of methanol reaction with PET therefore cannot exceed 2x32/192=0.33. For one tonne of PET, a maximum of 0.33 tonne of methanol can be consumed, costing 100 €.
    - Where the PET contains impurities, be it polyethylene, cotton fibres or pigments, the amount of methanol that reacts can only be lower, not higher.
    - It is important to understand that exactly the same amount (and therefore cost) of methanol is needed for production of virgin DMT for virgin PET, where DMT is made by reacting terephthalic acid with methanol. **The cost of methanol reacting is**

[38] Gaudillat, P., Marschinski, R. and Saveyn, H., Economic viability of chemical recycling – Current and future perspectives, Publications Office of the European Union, 2026
[39] Methanol - Price - Chart - Historical Data - News

therefore irrelevant when comparing the cost of chemically recycled PET with that of virgin PET.

- In both cases, methanol is produced in the condensation polymerisation reaction of ethylene glycol with DMT, which must be removed from the reaction mixture by distillation to drive polymerisation towards completion, i.e. towards sufficiently long polymeric chains.

2. **Not reacting chemically**, but merely acting as a solvent to reduce the viscosity of the reaction mixture (in a solution process), being circulated in a distillation or vapour-phase process, or shifting the equilibrium reaction towards the right side, i.e. the monomers. In all of these cases, methanol is used, but not consumed. Where methanol takes up impurities, it can be easily purified by distillation. The economically relevant operational cost will be the energy demand for distillation; this will likely not be a major driver, and will not be fundamentally different in magnitude from the virgin process.

In short, as actual methanol consumption is likely similar in the virgin and the depolymerisation process, **the costs associated with methanol are likely similar in both cases**. The cost of raw materials (i.e. petrochemicals vs. sorted waste) is likely the reason for larger disparities.

PET depolymerisation is not struggling to gain pace because of a lack of technological readiness or of strongly unfavourable economics. It is also not needed economically: mechanical recycling of PET occurs at a large scale. PET bottles are collected at a large scale; they constitute a highly homogeneous, clean and pure waste stream, where intruding materials are easy to spot and remove. PET bottles are turned into new PET bottles in mechanical recycling, and downcycling (the reverse process not being easily feasible) to fibres for textiles is also common. **All in all, chemical recycling is a technologically and economically competitive process compared to virgin manufacture, but it remains marginal as it is outcompeted on simplicity and quality by mechanical recycling of PET.**