Analysis from an environmental perspective of the proposed EU legal framework for pyrolysis and gasification

Policy Paper
April 2023

ecos
Deutsche Umwelthilfe
ZERO WASTE EUROPE

Contents

Executive Summary

Analysis from environmental perspective of proposed EU legal framework for pyrolysis and gasification

On behalf of the European Commission, the Joint Research Center (JRC) recently published two studies, which intend to provide a basis for a legal framework for chemical recycling. One study deals with the definition of the term recycling as well as possible calculation methods for recycling technologies. The second study deals with an environmental and economic assessment of plastic waste recycling techniques with a specific focus on chemical recycling methods. According to European environmental NGOs, these studies set the wrong priorities and could encourage problematic policy decisions on pyrolysis and gasification of plastic packaging waste; and are, therefore unsuitable, as a basis for political decisions.

We would like to note at the beginning that the term *chemical recycling* is not uniformly used, and there is currently no legal definition. A lot of different technologies are summarised under this single term, which creates confusion when discussing this topic.

This paper does not aim to cover all technologies and excludes, therefore, technologies such as solvent-based dissolution and chemical depolymerisation relying on less energy-intensive processes. The scope of this assessment includes techniques performing thermo-chemical decomposition of plastic waste to molecular-level feedstock, with a focus on pyrolysis and gasification of plastic packaging waste. From an environmental point of view, these technologies should be classified as chemical recovery techniques, and can therefore only contribute marginally to reducing impacts from plastic production.[1]

The *Circular Economy Action Plan (CEAP)* defines a strategy for a climate-neutral, resource-efficient and competitive economy.[2] In this context, after measures on prevention and reuse have been addressed, recycling has a key role to play in further enhancing the circularity of materials. In line with this narrative, to develop resource-efficient processes, the classification of any technologies as recycling should ensure a high recycling yield, meaning that a high amount of materials is kept in the loop. We are calling for a **threshold of at least 80% of the carbon content of plastic waste converted into new products when discounting all**

---

[1] DUH, ECOS, ZWE, *Chemical Recycling and Recovery, Recommendation to Categorise Thermal Decomposition of Plastic Waste to Molecular Level Feedstock as Chemical Recovery*, 2021

[2] European Commission, *Circular Economy Action Plan - For a cleaner and more competitive Europe*, 2020

pre-treatment and post-treatment processes including repolymerisation.[3] In other words, it means that 80% carbon content for the input becomes recycled plastic feedstock ready to be integrated into a new product. Following the waste hierarchy, technologies not meeting this threshold will be classified as *chemical recovery* techniques.

Recommendations

Our paper provides the following recommendations for policy-makers when assessing the definition of recycling:

- To be classified as recycling technology, the process should meet a threshold of at least 80% of the carbon content of plastic waste converted into new products when discounting all pre-treatment and post-treatment processes including repolymerisation;
- The process should deliver safe, non-toxic, and decontaminated products, by-products, and waste, without having to require dilution steps with virgin materials;
- The system boundary defining recycling activity should be set after the repolymerisation step to allow for a comparison of different process outputs and discount all transformation/energy losses;
- Public funding should not be given for the construction of pyrolysis and gasification plants, as the environmental value of these techniques is still not proven and the risks exceed the benefits;
- The reference scenario presented in the study for incineration considers that most EU incinerators are generating electricity and not energy, which is the contrary in reality. Such assumptions highly increase the overall efficiency rate of incineration.

---

[3] DUH, ECOS, ZWE, *Pledge - Setting a truly circular recycling system*, 2022

The study "Towards a better definition and calculation of recycling"

A lot of **questionable assumptions have been made regarding different recycling technologies** in the Joint Research Center (JRC) study.

Mechanical recycling appears as a field lacking investment in recent years, and the JRC study suggests limited room for improvement. However, innovation in mechanical recycling is ongoing and allows for a high quality of recycled materials.[4] Mechanical recycled high density polyethylene (HDPE) is recognised by the European Food Safety Authority (EFSA) to be compliant with EU regulations on products and practices intended to be in contact with food. The high dependence on the quality of input waste is being reduced with the introduction of additional sorting, washing, and extrusion steps in existing technologies. Currently, mechanical recycling schemes are mainly focused on rigid packaging such as PET bottles, and much less on flexible packaging, of which recycling rates remain low. However, innovative improvement steps based on additional sorting units, hot washing, improved extrusion, and deodorisation broaden the types of inputs considered by mechanical recycling. The above-mentioned steps also improve the quality of recyclates, which is suitable for the same application category, and therefore links to the quality of virgin grades.[5]

On the contrary, for pyrolysis and gasification, these assumptions seem overly too positive. First, these technologies require a high amount of energy to run, and there is significant leakage of plastic materials as around 53% of the carbon content is lost in the process or turned into fuels. This must be equally considered as a leakage of materials from a circular management perspective.[6]

Secondly, despite the industry's claims to handle all non-recyclable waste, pyrolysis needs rather homogenous input to run: at least 85% of pure polyolefins.[7] It cannot handle more than 1% of polyvinyl chloride as the chlorine gas corrodes the metallic parts of the pyrolysis reactor, affecting the functional unit of the process.[8]

Thirdly, pyrolysis is often promoted as the only solution to recycle polyolefins meeting requirements for contact-sensitive applications, such as food-contact applications. However, a study shows that there is no

---

[4] TOMRA, *Advanced mechanical recycling: Enabling true circularity for plastics, now*, 2022

[5] Sciences Direct - Waste Management, *Quality evaluation and economic assessment of an improved mechanical recycling process for post-consumer flexible plastics*, 2022

[6] Öko-Institut, *Climate impact of pyrolysis of waste plastic packaging in comparison with reuse and mechanical recycling*, 2022

[7] Eunomia, *Feedstock Quality Guidelines for Pyrolysis of Plastic Waste*, 2022

[8] M.I. Jahirul, *Transport fuel from waste plastics pyrolysis – A review on technologies, challenges and opportunities*, 2022

food-grade recycled plastic made from olefins because of uncontrollable toxic chemicals created in the recycled plastic.[9]

Furthermore, the capacity to obtain infinite recycling loops is uncertain as the material quality does likely change following each recycling round, and should therefore be characterised consistently.[10]

Finally, a large amount of input is lost in the process, requiring a continuous need for virgin materials to feed the process.

Based on the above-mentioned points, we think that both technologies should not be classified as recycled ones, and this position can also be found in the EU legislative framework. Indeed, these technologies are not covered by Regulation 2022/1616 on recycled plastic materials and articles intended to come into contact with foods, as they produce monomers from a fuel-like mixture. In addition, this mixture is considered as waste recovery back into substances under the REACH Regulation, which further supports the classification of these technologies as chemical recovery ones.

When defining the **recycling system boundaries, the study goes in the right direction.**
The final measurement point is after the polymerisation step, allowing to have comparable recycled outputs (product) from the different technologies (i.e. polymer) that do not need to undergo further processing before their use in a final product. This is in line with the calculation of recycled municipal waste in the Commission Implementing Decision (EU) 2019/1004. This means that there are no additional steps, such as further purification, where losses might occur. However, this approach should also be applied if the monomers are sold to another company to compare fully different recycling technologies.

The purpose of recycling technologies is to process waste feedstock, which is rightly mentioned as the only basis to estimate the recycling yield of any technology. From this perspective, recycling yield claimed for pyrolysis requires specific attention as the process relies on a dilution step to meet the steam cracker requirements. As stated in the study, the usual dilution factor is 10 units with virgin material input.

We support the fact that process losses should not be accounted for as part of recycled content, and this approach should also cover inherent losses as they are not part of the final product. In the case of pyrolysis, inherent losses represent 30% of the waste input due to the high pressure and temperature required by the process.[11]

We also support the recognition that the use of the "mass balance" chain of custody is only required for assessing recycled output from thermo-chemical technologies (i.e. pyrolysis and gasification), which further supports categorising these technologies as chemical recovery techniques. In this sense, it is important to stop

---

[9] Fraunhofer Institute, *Identification and Evaluation of (Non-)Intentionally Added Substances in Post-Consumer Recyclates and Their Toxicological Classification*, 2023
[10] ACS, *Technical, economic, and environmental comparison of closed-loop recycling technologies for common plastics*, 2023
[11] Eunomia, *A Comparative Assessment of Standards and Certification Schemes for Verifying Recycled Content in Plastic Products*, 2021

creating confusion and put an end to calls claiming that chemical recycling in its overall needs a flexible, site or multisite mass balance approach to scale up. Indeed, there is already proof that chemical recycling technologies can run their process based on either a segregated or a batch level mass balance model.[12]

In the case when a mass balance chain of custody is required, it should apply across all recycled materials produced in the recycling process, regardless of the type (e.g., polymers or non-polymers) as long as they can be considered recycled products. Concerning how to allocate input, we agree that the mass-based rules presented in the document are the right approach, which requires making the allocation proportionally between waste and virgin feedstock. Such an approach reduces the uncertainties in comparison to energy- or price-based allocation. The latter models would rely too heavily on market orientations and possible speculation in the case of price-based allocation, or would further reinforce the dependence on the geopolitical situation in the case of energy-based allocation.

Furthermore, the study clearly states that traceability is only feasible between actors, not within the process itself. As consumers need a reliable recycling definition and transparent calculation methods, a material should only be claimed as "recycled" if it can be distinctly traced back to the waste input.

Certification schemes EN 15343 on plastic traceability and reporting requirements for recycled content should follow the first option mentioned in the JRC study: reporting is established at the final transformation stage using the mass balance approach and appropriate traceability schemes. The final allocation should be based on the proportional allocation of the recycled content to ensure the level of correlation between the likelihood of the physical and chemical content of a product and the claims made on them. The two other options presented by the JRC break any traceability within the value chain up to the final products and are not compliant with the above-mentioned standard, and equate to book and claim practices. Furthermore, they would not meet the recycling system requirements as it does not entail the repolymerisation stage, which may not reflect actual yields from downstream operators.

The presented framework by the **JRC study goes further and adds another dimension when assessing recycling activities by introducing a qualitative dimension**. Indeed, it offers a quantitative way to assess the quality of recycling and makes a comparison among different recycling techniques. However, this comparison lacks adequate considerations about the overall presence, quantity, and the fate of hazardous chemicals associated with an applied recycling process/technology. While one of the main requirements to be taken into account when assessing a given secondary material quality is rightly to indicate information on the chemical compounds present in the secondary material, defining such a requirement as "chemical load" does not seem really accurate. Such a term should rather directly refer to "substances of concern/contamination load" because the main focus of related 'legal boundaries' (legislation and standards that are applicable on the use of secondary materials) is chemical safety.

---

[12] Pyrowave, *Pyrowave Sets New Standard With 100% Traceable Recycled Styrene*, 2022

Environmental and economic assessment of plastic waste recycling

The JRC study rightly provides an assessment of the environmental impacts of chemical recycling technologies since, until now, independent and comprehensive lifecycle assessments (LCAs) on pyrolysis and gasification of packaging plastic waste are missing.[13]

However, several limitations persist throughout the study, especially when it comes to data access - especially regarding the input-waste stream entering the recycling processes, the destination of recycled product output and waste flows, as well as the economic assessment of different technologies. **We, therefore, support the JRC call to have more access to transparent and qualitative data allowing a comprehensive assessment of different technologies.**

In our opinion, before introducing any legislative or economic incentives, a proper and comprehensive assessment should be made in line with the precautionary principle established in the EU legislative framework. When looking at the current legislative developments, especially on packaging and packaging waste, special care should be taken not to falsely generalise statements from specific processes and waste streams to the general term *chemical recycling* and draw unjustified conclusions. We wanted to reiterateb that, in this assessment, we are focusing on pyrolysis and gasification.

The **main limitation of the study is the access to reliable, transparent and complete data**, despite repeated calls for data from the authors.

This is especially relevant for waste inputs, in which data was lacking from two perspectives: the characterisation of waste inputs (i.e. detailed composition and possible classification), and its nature (i.e. post- or pre-consumer waste) and origin. This data gap is even more important when considering that a clear assessment of the input is required to estimate the recycling yield of any technology, as defined in the previously assessed JRC study on recycling. Additionally, data on input quality are very relevant to assess alternative scenarios such as prevention or mechanical recycling. The study's reference assessments rely on templates handed in during stakeholder consultations, so data collection cannot be rated as completely independent as its reliable verification is hardly possible.

---

[13] EEB, DUH, ECOS, GAIA, NABU, Rethink Plastics, ZWE, Understanding the Environmental Impacts of Chemical Recycling, 2020

In addition, there was no consistency in the level of detail between inputs received from the industry data, and some elements (i.e. by-products, waste flows, operational costs) were even lacking. In the case of gasification, for example, an environmental assessment is completely missing from the JRC study. The comprehensiveness of the technical data for pyrolysis can also be doubtful since the technological readiness has not achieved the industrial scale, and existing technical problems relate in particular to upscaling steps. To mitigate this situation, many assumptions when defining the quality of input waste have to be made, especially in the case of flexible packaging waste made of mixed polyolefins, which are the basis of approximately two-thirds of packaging. **Therefore, the outcomes of this study should, in our opinion, be considered with precaution.**

The problem to access qualitative and quantitative data - notably regarding waste input characteristics - should be mitigated by Regulation 2022/1616, which requires data on waste input for so-called innovative recycling processes for food-contact applications. However, pyrolysis that produces monomers derived from an oil process seems to be exempted from the Regulation 2022/1616.

Although the data basis of the study can raise doubts, we would like to highlight one result of the study showing that for mixed polyolefins, climate impacts from pyrolysis exceed those of mechanical recycling. Literature data supports this result and may suggest even more significant differences regarding the climate impact between pyrolysis and mechanical recycling of mixed waste plastic packaging.[14] The problem of accessing reliable and concrete data has been repeatedly named throughout the study and is not limited to defining waste input, as other relevant flows are also impacted by this, notably recycled product output and waste flows.

Ensuring access to more transparent data taken from the primary dataset will allow having more detailed information on first the specific quality of the feedstock used for chemical recycling (i.e. quality requirement, level of acceptable impurities, and pretreatment required), but also relevant parameters when assessing environmental impact of any process, (i.e. energy demand, output characterisation, pollutant fate, yield). This will enable an independent assessment of plausibility, as well as an evaluation to what extent these technologies can truly complement mechanical recycling or contribute to the circular economy.

The JRC correctly concludes from the study that decisions on treatment processes should be based on maximising output and minimising environmental impacts, but ignores that this aim presumably conflicts with actual performance of pyrolysis and gasification. The study rightly summarises the current technical deficits of pyrolysis and gasification. The main disadvantages listed in the study for these technologies are high energy demand, high sensitivity to input impurities, and low yields. For pyrolysis of relevant plastics such as PP or PE, low yields of 45% and 40% respectively were reported by the JRC. For PVC and PET, no yield can be expected at all. Critically, the JRC does not conclude that such low yields for relevant plastic types are a clear signal against the treatment of mixed packaging plastic waste by pyrolysis plants, as

---

[14] Ökoinstitut, *Climate impact of pyrolysis of waste plastic packaging in comparison with reuse and mechanical recycling*, 2022

the possible contribution to closed-loop recycling is small. In line with the *CEAP* aiming to establish a resource-efficient economy, these technologies shall, therefore, be classified as chemical recovery techniques.[15]

Particularly, **the study does not discuss important aspects of a comprehensive regulation of pyrolysis and gasification that is embedded in an integrated circular economy strategy for packaging.** Allowing pyrolysis and gasification to contribute to recycling and recycled content targets would definitely influence waste streams established for mechanical recycling, as well as lower incentives for reuse, waste prevention, and recyclability. The study assumes an optimal combination of mechanical and chemical recycling and ignores the risk of mechanically recyclable materials being treated by pyrolysis or gasification plants under higher mass losses and high energy demand once these facilities are established. The JRC also underestimates the risks of energetic use of outputs for a circular economy, and instead lists the hydrogen production from gasification as an advantage of the technology. All these effects from pyrolysis and gasification may overlay environmental effects from the processes themselves.

While chemical recycling is presented and analysed by the JRC as an innovative technology with huge potential, alternative scenarios appear little innovative and old-fashioned. For example, pyrolysis and gasification are compared to the lowest bar - incineration - for several waste streams. Yet incineration of plastics is a growing concern due to its high climate impact; and several member states have set targets to reduce their reliance on waste incineration.

Building on an already existing and well-functioning system, innovation in mechanical recycling is ongoing and allows for a higher quality of recyclate and a broader scope of waste inputs, which is not depicted in the current study. Additional innovation steps will complete the already efficient and environmentally-sounded system, and this is particularly relevant with political and economic incentives.[16] However, for all systems, any incentives should be based on a precautionary approach.
Other important impactful measures are waste prevention (prevention, reuse systems) as well as significantly improved design for (mechanical) recycling. It is likely and desirable that these potentials will be exploited in the coming years, which in turn would have an enormous impact on the amount and composition and quality of collected plastic waste. Indeed, 80% of the end-of-life greenhouse emissions could be avoided with a better design in the first place.[17]

Regarding the assessment of incineration, the referent efficiency of the process is based on the incineration system generating heat and power (CHP). This picture does not represent the actual average efficiencies of EU incinerators, which mostly generate power. The latter has a lower conversion efficiency than that described in

---

[15] DUH, ECOS, ZWE, *Chemical Recycling and Recovery, Recommendation to Categorise Thermal Decomposition of Plastic Waste to Molecular Level Feedstock as Chemical Recovery*, 2021
[16] TOMRA, *Advanced mechanical recycling: Enabling true circularity for plastics, now*, 2022
[17] European Commission, *Circular Economy Action Plan - For a cleaner and more competitive Europe*, 2020

the JRC study. A recent study established an efficiency rate of electricity generation from waste in the mid-20s in the best cases.[18]

Toxicity and the release of air contaminants are important indicators to consider when assessing any technology. This is even more relevant for pyrolysis and gasification because both processes are known to generate highly polluted waste streams and air contaminants.[19,20] Although the JRC presents results for toxicity in the annex, this issue is not integrated into the discussion and conclusions of the study. Since former studies often failed to reliably assess toxicity risks, it would be important to get information on how the JRC assesses data quality related to pollutants and their fate.[21] In particular, it would be of great importance for the public to know which and to what extent pollutants are to be expected as emissions from pyrolysis and gasification plants.

Due to the limited access to data on the economic viability of the different processes, the conclusion regarding the economic viability of physical and chemical recycling should not be considered definite. In the JRC study, the life-cycle costing (LCC) work considering all the cost that occurs during recycling activities relied mostly on secondary data and market price for secondary and primary plastics. Indeed, no access to the primary dataset was granted based on claimed confidentiality and competitiveness purposes and very little information on operational aspects was provided by stakeholders. Lacking this data hampers the possibility of truly determining the economic viability of the assessed technologies as the reference parameters are feedstock prices, capital and operational expenditures and output prices.

The other important factor when determining the economic viability of any technology is the revenue that relies on the output prices. The latter in the study was based on the prices of the corresponding virgin-based products. This influences the estimation of the real costs in both ways, either underestimating or overestimating economic viability.

When focusing on the specific case of pyrolysis, which is supposed to be economically viable by 2033, a lot of questionable assumptions have been made in the study. Indeed, this process typically relies on dilution practices requiring fossil fuel feedstock to meet the steam cracker requirements. Therefore, any increase in fossil fuel prices will have a strong impact on the economic viability of pyrolysis, which is a technology that strongly relies on virgin materials to deliver. However, defining the date of 2033 as the year of economic viability is based on the assumption that the increase in the naphtha price will only influence the output product price and not the cost of the feedstock. The above-mentioned assumption, also recognised by the authors themselves is, in our opinion, not realistic. Indeed, recyclers are price takers determined, in most cases, by virgin producers. Therefore, any increase in the plastic feedstock in the first place will impact the economic viability of technologies. In addition, in the case of pyrolysis, steam crackers have specific requirements that the waste input feedstock must meet. Such requirements might lead to further purification steps, thus further

---

[18] Equanimator Ltd, *Debunking Efficient Recovery: The Performance of EU Incineration Facilities*, 2023

[19] Verma, R. and all, *Toxic pollutants from plastic waste - a review*, 2016

[20] Rollinson, A, Oladejo, J.M., *Chemical Recycling: Status, sustainability and environmental impacts*, 2020

[21] EEB, DUH, ECOS, GAIA, NABU, Rethink Plastics, ZWE, *Understanding the Environmental Impacts of Chemical Recycling*, 2020

challenging the economic potential, and potentially the environmental performance of the technology - as rightly admitted in the study. The lack of models validated with reliable experimental data for plastic waste pyrolysis further questions the scaling-up capabilities of the process. Following these reasons, we hold the opinion that **public funding should not be given for the construction of pyrolysis and gasification plants since the environmental value of these techniques is still not proven and risks exceed benefits**.

Conclusions

As analysed, the two studies published by the JRC on behalf of the European Commission are important steps towards more clarity around the concept of recycling, which is now highly debated by the development of 'chemical recycling'.

We, environmental NGOs, support this initiative showcasing important differences and discrepancies between all technologies. The main point both studies underline is the difficulty to apply one approach that fits all technologies. This further supports the need for differentiation.

However, in our opinion, techniques performing thermo-chemical decomposition of plastic waste to molecular level feedstock (i.e. pyrolysis and gasification) should not be classified as recycling, but as *chemical recovery* techniques, due to their high environmental impacts, limited efficiency, and high energy requirements; and can therefore only contribute marginally to reducing impacts from plastic production. This approach would ensure policies do not rely on techniques that have low yields, high energy demand/climate impact, and high sensitivity to impurities; and would avoid the wrong economic and political incentives.

To ensure the highest compliance with the *CEAP* to develop a climate-neutral, resource-efficient, and competitive economy, the classification as plastic recycling technology should particularly rely on the recycling yield threshold, low energy demand, low toxic emissions. In this context, we are calling for a threshold of at least 80% of the carbon content of plastic waste converted into new products when discounting all pre-treatment and post-treatment processes including repolymerisation. The process should deliver safe, non-toxic, and decontaminated products, by-products, and waste, without having to require dilution steps with virgin materials. Following the waste hierarchy, technologies not meeting this threshold should be classified as recovery techniques, and most of the incentives should first favour reduction, reuse, waste prevention, ecodesig,n and design for recycling - which are measures with proven effect and already at scale.

There is no time to waste in creating a regulatory framework for these technologies at the bottom of the waste hierarchy and risk undermining the credibility of the currently established recycling structures.

ECOS is an international NGO with a network of members and experts advocating for environmentally friendly technical standards, policies and laws. We ensure the environmental voice is heard when they are developed and drive change by providing expertise to policymakers and industry players, leading to the implementation of strong environmental principles. www.ecostandard.org

Environmental Action Germany (DUH) has been campaigning to preserve the natural foundations of life for more than 40 years. In doing so, it brings together protecting the environment with consumer protection like no other organisation in Germany. www.duh.de

Zero Waste Europe is the European network of communities, local leaders, experts, and change agents working towards the elimination of waste in our society. We advocate for sustainable systems and the redesign of our relationship with resources, to accelerate a just transition towards zero waste for the benefit of people and the planet. www.zerowasteeurope.eu

Zero Waste Europe gratefully acknowledges financial assistance from the European Union. The sole responsibility for the content of this material lies with Zero Waste Europe. It does not necessarily reflect the opinion of the funder mentioned above. The funder cannot be held responsible for any use that may be made of the information contained therein.

Authors: Lauriane Veillard, Dorota Napierska (Zero Waste Europe), Mathilde Crepy, Fanny Rateau (ECOS), Marieke Hoffmann, Kerstin Podere (Deutsche Umwelthilfe)
Editors: Aline Maigret, Janek Vähk, Ana Oliveira (Zero Waste Europe)
Date: April 2023

General information: hello@zerowasteeurope.eu
Media: news@zerowasteeurope.eu
Cities-related topics: cities@zerowasteeurope.eu

zerowasteeurope.eu
www.zerowastecities.eu
www.missionzeroacademy.eu