Assessment of the definition of recycling

Background paper

WP4 of the project Support for Circular Economy Action Plan 2.0- Part 1: Short term actions (CEAPAA1)

Elena Garbarino, Pelayo Garcia-Gutierrez, Glen Orveillon, Gian Andrea Blengini, Simone Manfredi, Davide Tonini

Contents

1 Introduction

The study on the *"Assessment of the definition of recycling*" is part of a broader action on the "**Support for Circular Economy Action Plan 2.0- Part 1: Short term actions (CEAPAA1)**", that the Joint Research Centre (JRC) is carrying out in collaboration with DG ENV, within the context of the **European Green Deal** and the **Circular Economy Action Plan 2.0**.

The 2008 Waste Framework Directive (2008/98/EC) and subsequent amendments (European Commission, 2018) established that waste legislation and policy of the EU Member States shall apply as a priority order the following waste management hierarchy: preparing waste for reuse, recycling, recovery, and disposal. The Directive assumes that following this order leads to the best overall environmental outcome, yet it opens to life cycle thinking and assessment as a tool to identify the preferable environmental option on a case-by-case basis.

Recycling of waste is defined as "*any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. 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*". Specific calculation rules for recycling have later been implemented in Commission Decision 2011/753/EU (European Commission, 2011), Commission Decision 2019/1004/EU (municipal waste; European Commission, 2019a), and Commission Decision 2019/665/EU (packaging waste; European Commission, 2019b) that amended Decision 2005/270/EU. The Commission regularly receives requests from the industry and Member States to revisit the definition and calculation rules to allow more innovative technologies to be considered recycling or contribute to recycling objectives and secure legal certainty for their investments. This, for instance, concerns chemical recycling and other processes that produce simultaneously fuel and chemicals/material. These requests often call for clarification of the existing rules on the calculation of the recycling targets, namely, as part of the Commission Decision 2019/1004/EU (European Commission, 2019a) and 2019/665/EU (European Commission, 2019b). Uncertainty on the definition of recycling also applies to recycling processes chains that treat waste streams other than municipal waste and packaging waste (e.g. construction and demolition waste CDW, tyres) and that contribute to functional and non-functional recycling (UNEP 2011). These questions are particularly relevant as the stakeholders are looking for opportunities to increase their recycling performance in view of the ambitious recycling targets in EU legislation (mainly for packaging waste and Municipal Waste). While this represents an opportunity to increase recycling of challenging waste materials (e.g. plastic packaging waste, for which current EU recycling rates of what is effectively recycled are estimated to be 14-25%; see Antonopoulos et al., 2021), the overall objective of facilitating and achieving high-quality recycling shall remain the main guiding principle.

2 Objectives of the study

The study aims to produce a technical proposal to support a possible revision of the calculation rules provided in Commission Decision 2011/753/EU as last amended by Commission Implementing Decision 2019/1004/EU related to the reporting and calculation of recycling targets for municipal waste and Commission Decision 2005/270/EU as last amended by Commission Implementing Decision 2019/665/EU related to reporting and calculation of targets for packaging waste. This need arises in particular with respect to those processes that are currently not included (i.e. for which there is no clarity or guidance on how to quantify recycling rates). This is for example the case of chemical recycling processes that convert plastics waste, bio-waste, or wood waste into chemicals, materials, fuels, and energy. The concept of 'mass balance approach' to quantify the share of recycling in processes that simultaneously produce materials, chemicals, fuels, and energy has been introduced at Art. 3(8) of 2019/1004/EU and at Art. 6c(i) of 2019/665/EU but specific calculation rules are not provided. The study, as exploratory research, further aims to provide an operational definition of quality of recycling. In view of the above, the **objectives** of the study are threefold:

1. To identify any relevant recycling process that is excluded from the current definition of recycling and on which further assessment and guidance is necessary to define appropriate calculation rules.
2. To identify appropriate calculation rules for the estimation of the recycling rate for such processes (with special attention to chemical recycling).
3. To discuss and suggest potentially relevant approaches for defining quality of recycling.

This background paper is a working document for an online workshop, which will take place in June 2021, and the related stakeholder consultation. This paper and the outcomes of the consultation may serve as a basis for producing the technical proposal aimed at refining the definition of recycling.

3 Identification of recycling processes to be further analysed

Drawing upon the scientific and technical literature, the main recycling processes currently excluded from the definition of recycling rules in Commission Decision 2019/1004/EU and 2019/665/EU appear to be chemical recycling – based processes. This group includes different technologies, such as glycolysis, solvolysis, gasification and pyrolysis where multiple outputs are generated ranging from fuels to materials and chemicals. These technologies may be relevant for waste streams such as challenging plastic waste (see e.g. Ragaert et al., 2017 and Civancik-Uslu et al., 2021), but also, for biomass waste to produce high-value products such as animal feed, succinic acid, lactic acid, polylactic acid, as illustrated in recent analyses for the case of food waste (Albizzati et al., 2020). These biowaste valorisation technologies (sometimes referred to as waste refineries or biorefineries) are known to generate multiple outputs, where biogas and other gases (methane, hydrogen, etc.), often used as fuel, are co-produced along with chemicals and materials and constitute a significant portion of the whole mass flow and of the process revenues. It could also be argue that some of these gases can be used as feedstock to produce other chemicals or materials, as it may be the case with hydrogen (i.e. not only as fuel). Some of the same issues apply to processing of wood waste in similar multi-output biorefineries or pyrolysis plants generating materials, chemicals, and energy, as illustrated in Ajao et al. (2021) and Papageorgeou et al. (2021), respectively.

4 Impacts on the calculation rules of recycling rates

As mentioned in section 1, recycling rules to quantify the share of material recycled out of a process are provided in Commission Decision 2019/1004/EU (European Commission, 2019a) and Commission Decision 2011/753/EU (European Commission, 2011) as well as Commission Decision 2019/665/EU for packaging waste (European Commission, 2019b). In Commission Decision 2019/1004/EU, calculation rules are provided for the following municipal streams: glass, paper and cardboard, metals, plastic, wood, textiles, composites, batteries, and WEEE (waste electric and electronic equipment). In Commission Decision 2019/665/EU, calculation rules are provided for the following packaging waste streams: plastic, wood, metals, glass, paper and cardboard, and 'other'. Commission Decision 2019/1004/EU further specifies calculation rules for the special case of metals recovery from bottom ash incineration (same in 2019/665/EU) and home composting of biowaste. It should be noticed that no specific calculation rules to estimate recycling rates are provided for multi-output processes that, via chemical or other forms of processing (e.g. thermal or biological), recover materials and chemicals (alongside energy and fuels) from the input-waste (e.g. plastic waste, food waste and other biomasses such as wood waste). Also, in this respect, consistency needs to be ensured with existing calculation rules for the same waste streams (calculation points, dry or wet basis mass balance approach, etc.).

5 Quality of recycling

The concept of quality of recycling is often used to distinguish between operations of recycling that achieve products of high-quality and those that, while recovering materials from waste, provide products of low-quality with lower market value and, at times, poor or no further recyclability when reaching their end-of-life. Different terms are used when referring to high quality recycling, such as "functional" recycling (as opposed to non-functional recycling or downcycling).
A lack of clarity on what 'quality' means is a crucial obstacle to the conception of robust policy measures addressing recycling. Existing interpretations are as disparate as relating to chemical purity, or to environmental benefit. A few notable attempts of defining quality in recycling are described herein.

- Grant et al. (2019) defines quality as "*The extent to which, through the recycling chain, the distinct characteristics of the material (the polymer, or the glass, or the paper fibre) are preserved or recovered so as to maximise their potential to be re-used in the circular economy*". These characteristics vary by material but may include, for example, food-contact suitability, structural characteristics (i.e. uniformity and viscosity), clarity and colour form, and odour. Such definition is based on the practical utility of the material in the circular economy, and on easily identifiable characteristics of materials within the recycling chain. As such, it can be used as the basis for an operational approach to assessing the quality of recycling.

- Eriksen et al. (2018, 2019) assessed the thermal degradation, processability and mechanical properties of a range of reprocessed PET, PE and PP samples from source separated household plastic waste and evaluated the potential for closed-loop recycling by comparing such properties to those of the correspondent virgin products. An assessment of the quality and circularity potential is then proposed.
- Roithner and Rechberger (2020) propose a calculation of the recycling rate based on the exergy approach and illustrated how current recycling rate (as requested by Commission Decision 2019/1004/EU) do not capture the quality of the recycled material and/or the functionality of the recycling process (i.e. the quantity of material that is "actually" useful for further use in the economy to displace alternative virgin production; see UNEP 2011).
- Haupt et al. (2016) propose an in-depth analysis of the recycling of paper, cardboard, aluminium, tinplate, glass and PET from Municipal Solid Waste in Switzerland by splitting the recycling rates into closed-loop and open-loop collection rates and recycling rates, also adapting the UNEP 2011 definitions. The Authors considered that open loop recycling maximizes the amount of waste recyclate, but is irreversible as the secondary material are degraded in quality and cannot be used in the original application. In turn, closed-loop recycling also emphasizes quality aspects, and allows the return of the recycled material to the application in the previous service life. They concluded that the recycling rates (as adopted at the time of the analysis) are not suitable as performance indicators for the circular economy. While calculation rules for recycling rates have been recently revised by the Commission, they may still fail to describe the actual effect on circularity, i.e. the extent to which the recovered material can effectively provide the desired service or functions (i.e. displace virgin material).

In the case of metals, the definitions of functional and non-functional recycling (UNEP, 2011) are clear and seem well accepted in the scientific literature. For example, based on these definitions BIO by Deloitte (2015) proposed that functional recycling r*efers to recycling in which the element in a discarded product is separated and sorted to obtain secondary material displacing same primary material*, while non-functional recycling r*efers to recycling in which the element in a discarded product is collected and incorporated in an associated large magnitude material stream. This represents the loss of its function as it is generally impossible to recover it from the large magnitude stream.* These concepts have already been applied for EU flow and raw materials, including Critical Raw Materials (CRMs) (Talens Peiro et al., 2018; Passarini et al., 2018; Matos et al., 2020). Furthermore, the EU End of Waste criteria for metal scraps include the concepts of functional recycling and quality of the recycled materials (e.g. content of foreign materials, absence of visible oil, oily emulsions, lubricants or grease, etc.) (Regulation 333/2011, Regulation 715/2013, Muchová and Eder 2010a, Muchová and Eder 2010b; Muchová et al., 2011).

As an exploratory research, we will analyse how to introduce the concept of "functionality" by transposing the experience of metals and CRMs to other exemplary waste streams (such as plastic packaging waste, CDW). In this analysis, functional recycling is likely to be considered as high quality recycling. As for non-functional recycling, the characteristics defining an (open-loop) low-quality recycling and the ones making it not eligible for being considered recycling will be analysed in depth.

Some literature references already exist for plastic packaging waste and CDW. For example, in the former case, Eriksen et al. (2018) introduced the concept of *functionality, i.e. the ability of the system to provide recovered fractions of material quantities and qualities fulfilling the demands in a steady-state market (closed material loop situation)*, based also on Vadenbo et al. (2016). Eriksen et al. (2018) concluded that the inclusion of more targeted fractions in plastic sorting scheme offers higher resource recovery efficiency and that it is imperative to reduce the presence of impurities in the recovered plastic fractions and to give more emphasis on closing the loops for high-quality plastics.

References

Ajao, O. et al. (2021). Multi-product biorefinery system for wood-barks valorization into tannins extracts, lignin-based polyurethane foam and cellulose-based composites: Techno-economic evaluation. Industrial Crops and Products 167, 113435.

Albizzati, P.F., Tonini, D., Astrup, T.F. (2020). High-quality products from food waste: an environmental and socio-economic assessment. Sci Tot Env. doi: 10.1016/j.scitotenv.2020.142466.

Antonopoulos, I., Faraca, G., Tonini, D. (2021). Recycling of post-consumer plastic packaging waste in EU: recovery rates, material flows, and barriers. Waste Manage 126, 694-705. doi: 10.1016/j.wasman.2021.04.002.

BIO by Deloitte (2015). Study on Data for a Raw Material System Analysis: Roadmap and Test of the Fully Operational MSA for Raw Materials, Prepared for the European Commission, DG GROW

Civancik-Uslu et al. (2021). Moving from linear to circular household plastic packaging in Belgium: Prospective life cycle assessment of mechanical and thermochemical recycling. Res Cons Recycl 171, 105633.

Eriksen, M.K., Damgaard, A., Boldrin, A., Astrup, T.F. (2018a). Quality assessment and circularity potential of recovery systems for household plastic waste. J. Ind. Ecol. https://doi.org/10.1111/jiec.12822.

Eriksen M.K. et al. (2019). Closing the loop for PET, PE and PP waste from households: Influence of material properties and product design for plastic recycling. Waste Management 96, 75-85.

European Commission (2011). Commission Decision of 18 November 2011 establishing rules and calculation methods for verifying compliance with the targets set in Article 11(2) of Directive 2008/98/EC of the European Parliament and of the Council.

European Commission (2019a). Commission Decision 2019/1004; available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019D1004&from=EN.

European Commission (2019b). Commission Decision 2019/665; available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019D0665&from=EN.

European Parliament and the Council (2018). Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.150.01.0141.01.ENG&toc=OJ:L:2018:150:TOC (accessed June 2020).

Grant, A., Cordle, M. and Bridgwater, E., Quality of Recycling (2020). Towards an operational definition, Canfora, P., Dri, M., Antonopoulos, I. and Gaudillat, P. editor(s), Publications Office of the European Union, Luxembourg, ISBN 978-92-76-25426-3, doi:10.2760/225236, JRC122293.

Haupt et al., (2016) Do we Have the Right Performance Indicators for the Circular Economy? Insight into the Swiss Waste Management System. Journal of Industrial Ecology

Matos C.T, Ciacci, L; Godoy León, M.F.; Lundhaug, M.; Dewulf, J.; Müller, D.B.; Georgitzikis, K.; Wittmer, D.; Mathieux, F. (2020). Material System Analysis of five battery-related raw materials: Cobalt, Lithium, Manganese, Natural Graphite, Nickel, doi:10.2760/519827

Muchová and Eder (2010a). End-of-waste Criteria for Iron and Steel Scrap: Technical Proposals

Muchová and Eder (2010b). End-of-waste Criteria for Aluminium and Aluminium Alloy Scrap: Technical Proposals

Muchová, L., Eder, P., Villanueva, A., (2011). End-of-waste Criteria for Copper and Copper Alloy Scrap: Technical Proposals

Papageorgeou, A., Eazzi, E.S., Enell, A., Sundberg, C. (2021). Biochar produced from wood waste for soil remediation in Sweden. Sci Tot Env 776, 145953.

Passarini, F., Ciacci L., Nuss P. and Manfredi S., (2018). Material Flow Analysis of Aluminium, Copper, and Iron in the EU-28, doi 10.2760/1079

Ragaert, K., Delva,L., Van Geem, K. (2017). Mechanical and chemical recycling of solid plastic waste. Waste Management 69, 24–58.

Regulation (EU) 333/2011 establishing criteria determining when certain type of scrap metal cease to be waste under Directive 2008/98/EC

Regulation (EU) 715/2013 establishing criteria determining when certain types of scrap metal cease to be waste under Directive 2008/98/EC

Roithner, C. and Rechberger, H. (2020). Implementing the dimension of quality into the conventional quantitative definition of recycling rates. Waste Manage 105, 586-593.

Talens Peiro, L., Nuss, P., Mathieux, F. and Blengini, G. 92018). Towards Recycling Indicators based on EU flows and Raw Materials System Analysis data, doi:10.2760/092885

UNEP (2011). Recycling rates of metals. A status report. Available at: https://wedocs.unep.org/handle/20.500.11822/8702.