

# **CIRCULARITY MICRO-INDICATORS FOR PLASTIC PACKAGING**

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**Abstract:** *In the last decades, we witnessed a continuous global increase in the consumption of plastics, with the packaging sector being a large contributor to this effect. However, while plastic packaging presents positive aspects, and is commercially advantageous, its sustainability is a concern. Associated with this, we have a traditional practice of linear economy use of plastic packaging, designed for single-use and with little planning for end-of-life (EOL) management. Because of these factors, boosted by an irresponsible societal behavior with plastic waste, casually thrown in the street or in nature, a global environmental pollution crisis ensued. It is thus imperative and urgent that plastic packaging evolves past its current unsustainable state. To dissociate the use of plastics from direct environmental pollution, preserve and optimize existing resources, and maintain the economic value of polymeric materials, it is vital to increase circularity in the packaging sector. This change can be achieved through circular economy strategies. To evaluate their effect, many assessments and monitoring tools exist, including circularity indicators. However, the plethora of such tools in the literature have mismatched calculation methodologies, take considerable engineering expertise, and focus only on some aspects of the product life cycle. This paper provides an analysis of relevant circularity micro-indicators specifically for the packaging sector, while identifying guidelines and good practices for packaging. This study aims to contribute to the packaging sector transition to a more circular economy.*

**Keywords:** circular economy; circularity indicators; packaging; plastics

## 1 INTRODUCTION

Packaging waste is one of the critical problems that is leading the plastic environmental pollution and a focus of the U.N. sustainable development goals. In 2019, the total European (EU28+NO/CH) plastics converters demand were 50.7 million tonnes, where packaging (39.6%) by far represents the largest end-use markets. In 2018, 17.8 million tons of post-consumer plastic packaging were collected, which corresponds to more than half (61%, approximately) of post-consumer waste collected that year. In 2018, most packaging wastes are recycled (42%) or incinerated (39.5%) with energy recovery; however, this last technique is not viable due to toxic gases released during combustion (Dintcheva, Infurna and D'Anna, 2020).

Furthermore, packaging uses many types of polymers, almost all non-biodegradable. The material diversity and incorporated additives brings added problems to the recycling process, since each material varies in properties and reprocessing conditions (Casarejos et al., 2018). “The transition from the dominant linear economy to a model grounded in circularity by intention and design can build a new essential foundation for the market economy and packaging utilization” (Casarejos et al., 2018).

With a transition to the circular economy comes up the necessity to develop tools that aid the monitorization of this transition. In this context, the progression to a circular economy can be measured through circularity indicators (Saidani et al., 2019; Lonca et al., 2020). Different authors (De Pascale et al., 2021; Kristensen and Mosgaard, 2020) reviewed the most relevant micro-level CE indicators in the literature. According to these authors, there are about 30 circularity indicators to calculate a product's or company's circularity. However, not all are relevant to the packaging sector.

## 2 LEGISLATION FOR CIRCULAR PACKAGING IMPLEMENTATION

In October of 2018, Europe established the “Plastics Pact”, that consists in a local and regional initiative network that gathers the main stakeholder to implement solutions to one circular economy on plastics. Also, the new directive EU 2018/852 about packaging waste defined more ambitious sustainability goals. Last, in 2019 we had the Directive on the Reduction of the Impact of Certain Plastic Products on the Environment (EU 2019/904), the adoption of the single-use plastics directive, and the European green agreement of the UE commission. Consequently, to implement a circular economy in the packaging sector it is necessary to: (1) eliminate the unnecessary packaging through design reformulation and new delivery

models, (2) reduce discarded packaging and implement reutilization models where relevant, (3) implement 100% reusable, recycling or compostable plastic packaging, (4) disengage plastic material produced with finite resource consumption, and (5) prohibit dangerous chemical products in plastic packaging (Ellen MacArthur Foundation, 2020).

### 3 CIRCULARITY MICRO-INDICATORS RELEVANT FOR PACKAGING

We based our assessment on a compendium and categorization of existing circularity micro-indicators (Kristensen and Mosgaard, 2020), which defined 9 categories: recycling, remanufacturing, reutilization, life extend, resource efficiency, end-of-life (EOL) management, waste management, disassembly, and multidimensional indicators. Considering these 9 circular economy categories and focusing on the most common packaging (e.g. films, containers, and discardable packages), only four categories are directly applicable, namely recycling, waste management, EOL management, and Resource Efficiency. Here we consider the general use of packaging, such as a film or container for protection, storage, and accumulation of a product to be consumed, and not necessarily some very specific and customized forms of packaging. A representative schematic of the selected micro indicators is shown in Figure 1. The extensive list of source references with definitions of the micro-indicators can be found in the aforementioned review (Kristensen and Mosgaard, 2020).

From an analysis of each micro-indicator, we identified the most relevant for the packaging sector: Material Circularity Indicator (MCI), Recycling Index (RI), Reuse Potential Indicator (RPI), Circularity Calculator (CC), and Value-Based Resource Efficiency Indicator (VRE). These are all in the Recycling or Resource Efficiency categories. Other also relevant micro-indicators are: Model of Expanded Zero Waste Practice (EZWP), Material Reutilization Score (MRS), Eco-cost /value Creation (EVR) and Typology for Quality Properties (TPQ).

The MCI is relevant as it measures the materials flow considering the recycled content linked to the waste and its usefulness. The RI considers the total rate of recycling and recuperation of the product and recycling rate of the individual materials contained in the product. The RPI evaluates how similar the recovered material is to a waste or a resource (usefulness of the material between 0 and 1, where 0 means that all materials can be the disposal of because this material is similar to the wastes, and 1 means that all materials can be recovered because it resembles one resource). The CC calculates the recycled content of the product, considering the recycled content contributions through the original product and the recycled content, evaluating thus the potential value captured by the circular business model.

The VRE focuses on non-sustainable entry values to the economy in relation to the product, as energy, raw material, etc.

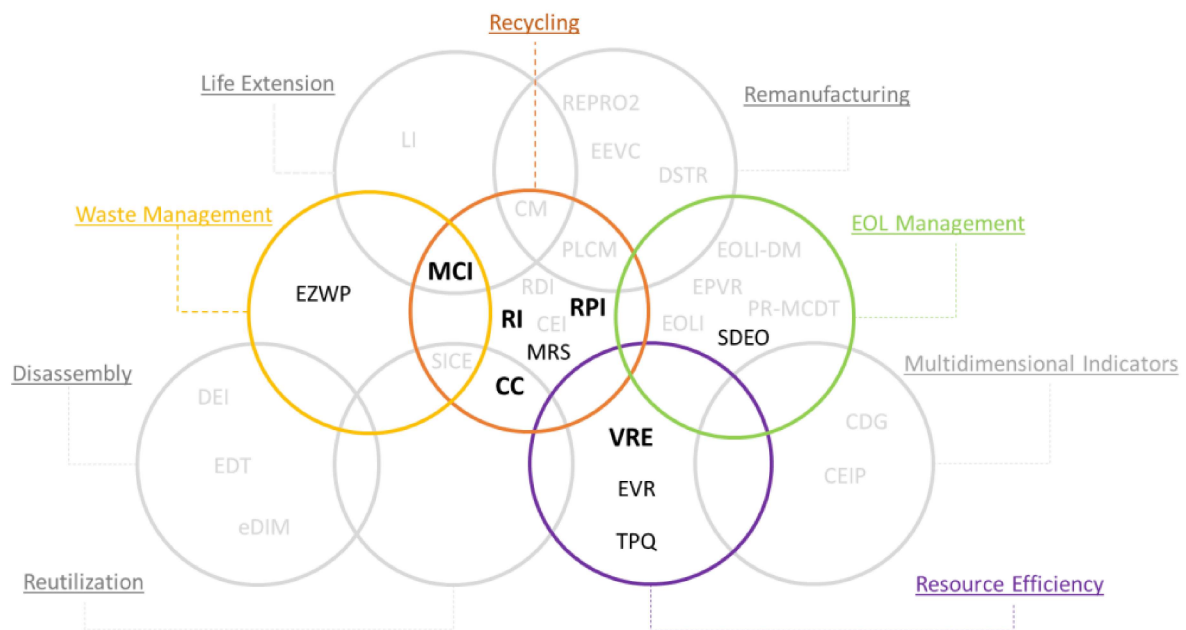


Figure 1: Micro-indicators relevant for estimating the circularity of packaging products (micro-indicators in bold black text are the most relevant, in regular black text are relevant, while grayed text ones are not relevant for the packaging sector).

The EZWP is relevant for the packaging sector because this indicator provides guidelines to promote circularity through the evaluation of the waste reduction hierarchy. The MRS depends on the amount of the material that is recyclable, biodegradable, and compostable to calculate a product's circularity. The EVR considers the resource efficiency by the eco-costs and value rate; however, this indicator is complex because it depends on an LCA evaluation to calculate the eco-costs. The TPQ is a tool that evaluates the properties of the inherent, designed, and created quality of materials, components, or products to improve the resource efficiency. The SDEO evaluates product design and how it facilitates the EOL management processes, through costs, revenues, environmental and social impact.

#### 4 GUIDELINES AND CONCLUDING REMARKS

Most micro-indicators evaluate parameters related to waste recovery when calculating circularity. For example, the amount of material collected for recycling or incineration, the value returned with product recycling, and the cost of waste recovery. The second most common parameters in the indicators are related to sustainable raw materials in the product. These parameters involve the amount of recycled or biodegradable materials, the content of

harmful additives, and cost and value of raw materials. A third also common set of indicator parameters is related to the recycling process efficiency. Last, a few micro-indicators relevant for packaging also evaluate parameters related to product and waste production prevention, easy separation of components, and unrecoverable waste production. From the evaluation of these parameters, we can identify guidelines and good practices to improve the circularity of packaging products:

- Packaging should contain recycled or biodegradable materials. These materials should not contain toxic elements, such as harmful additives, and should be recovered by the available EOL techniques, always bearing in mind the recovery of resources, and never their elimination. Further, recovery should be efficient and not produce unrecoverable waste.
- Packaging products should contain a design that allows easy separation of materials and components whenever it is vital to include different types of polymers. The plastic waste generated during the production process of packaging itself should be reduced to the minimum.
- At the EOL, waste should be recovered and applied in the conception of the same packaging product when possible, closing the resource cycle, or applied in other packaging products to reduce the use of virgin polymers.
- After that, following circular economic principles, the packaging product design should feature only one type of polymer in the same product and follow universal design solutions between different brands of that same packaging product to facilitate the recycling process.

As recycling is not the only solution for reducing packaging plastic waste pollution, producers and consumer associations should create collection locations and/or promote packaging reuse whenever possible, for example allowing refill when packaging does not become contaminated through use.

Through the increasing implementation of circular economy principles, reflected in the provided list of guidelines, we believe the packaging sector can shift towards a sustainable (and more circular) future, vital for modern society.

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## 5 REFERENCES

Casarejos, F. et al. (2018). Rethinking packaging production and consumption vis-à-vis circular economy: A case study of compostable cassava starch-based material. *Journal of Cleaner Production*, 201, pp. 1019–1028. doi: 10.1016/j.jclepro.2018.08.114.

Dintcheva, N. T., Infurna, G. and D’Anna, F. (2020). End-of-life and waste management of disposable beverage cups. *Science of the Total Environment*, 763, pp. 143044. doi: 10.1016/j.scitotenv.2020.143044.

De Pascale, A. et al. (2021). A systematic review for measuring circular economy: The 61 indicators. *Journal of Cleaner Production*, 281, pp. 124942. doi: 10.1016/j.jclepro.2020.124942.

Ellen MacArthur Foundation (2020). *Plastics and The Circular Economy*. Available at: <https://www.ellenmacarthurfoundation.org/explore/plastics-and-the-circular-economy> (accessed: july 28, 2021).

Kristensen, H. S. and Mosgaard, M. A. (2020). A review of micro level indicators for a circular economy. *Journal of Cleaner Production*, 243, pp. 118531. doi: 10.1016/j.jclepro.2019.118531.

Lonca, G. et al. (2020). Assessing scaling effects of circular economy strategies: A case study on plastic bottle closed-loop recycling in the USA PET market. *Resources, Conservation and Recycling*, 162, pp. 105013. doi: 10.1016/j.resconrec.2020.105013.

Saidani, M. et al. (2019). A taxonomy of circular economy indicators. *Journal of Cleaner Production*, 207, pp. 542–559. doi: 10.1016/j.jclepro.2018.10.014.