

Supplementary information to article

CIRCULARITY MICRO-INDICATORS FOR PLASTIC PACKAGING AND THEIR RELATION TO CIRCULAR ECONOMY PRINCIPLES AND DESIGN TOOLS

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The Material Circularity Indicator (MCI) results from subtracting 1 by multiplying the linear flow index (LFI) and a utility function $F(x)$, as demonstrated in **Equation S.1**. The result of this indicator varies between 0 and 1. If the product studied presents a completely linear material flow, the $MCI=0$; however, if this flow is completely circular, the $MCI=1$.

$$MCI = 1 - LFI * F(x) \quad \text{Equation S. 1}$$

The RDI indicator results from the sum of the three factors: the Simplicity Index of separation of materials, the Material Safety Index (MSI), and the assessment of technological maturity through the Technology Readiness Level (TRL), as shown in **Equation S.2**. The closer the result of this indicator is to 3, the more desirable it is to recycle the product under study.

$$D_{\text{Desirability}} = (D_{\text{Simplicity}} + D_{\text{MSI}} + D_{\text{TRL}}) \quad \text{Equation S. 2}$$

The Reuse Potential Indicator (RPI) is calculated through the ratio between the economic portion reusable through available technologies and the subtraction of the net marginal revenue obtained from the sale of the recovered material by the cost of its disposal in landfills, as we can see in **Equation S.3**. If $RPI=0$, it means the material is closer to being waste; however, if $RPI=1$ the material is closer to being a resource.

$$\text{Reuse Potential} = \frac{\text{Economically Reusable Portion}}{[\text{Net Marginal revenue} - \text{Disposal Costs}]} \quad \text{Equation S. 3}$$

The Circular Economy Index (CEI) is calculated by the ratio between the value of the material obtained from the recycling of end-of-life products, that is, the market value of the recycled material and the intrinsic value of the material that enters the recycling facility, as demonstrated in **Equation S.4**.

$$CEI = \frac{\text{Material value recycle from EOL Product(s)}}{\text{Material value needed for (re-)producing EOL product(s)}} \quad \text{Equation S. 4}$$

The Material Reutilization Score (MRS) involves the percentage of recycled material and rapidly renewable product content that the product contains, and the percentage of the products that are recyclable, biodegradable or compostable, as shown in **Equation S.5**.

$$MRS = \frac{\left[\frac{\% \text{ Recycled or rapidly renewable product content}}{3} \right] + 2 \left[\frac{\% \text{ of product recyclable or biodegradable/Compostable}}{3} \right]}{3} \times 100 \quad \text{Equation S. 5}$$

The Longevity Indicator (LI) is calculated by the sum of the product's initial useful life (A), the contribution of the reconditioned useful life (B) and the contribution of the recycled useful life (C), according to equation S.6.

$$\text{Longevity} = A + B + C \quad \text{Equation S. 6}$$

The Lifetime Contribution of Reconditioning (B), that is, how many additional months are gained due to the fact that products are returned, can be calculated through the product of the percentage of products returned (W), with the percentage of reconditioned products (X) and the useful life of the reconditioned product (U), as demonstrated in Equation S.7.

$$B = (W_1 \times X_1 \times U_1) + (W_1 \times X_1 \times W_2 \times X_2 \times U_2) \quad \text{Equation S. 7}$$

The Lifetime Contribution of Recycling (C) is the product of the percentage of products returned (W), with the percentage of recycled products (y) and the percentage of unrecoverable materials from the product (z), and can be calculated using Equation S.8.

$$C = \left[(A + B_1 + B_2) \times \left[\frac{(W_1 \times y_1 \times Z_1)}{(1 - W_1 \times y_1 \times Z_1)} \right] \right] + \left[(A + B_1 + B_2) \times \left[\frac{(W_1 \times X_1 \times W_2 \times y_2 \times Z_2)}{(1 - W_1 \times X_1 \times W_2 \times y_2 \times Z_2)} \right] \right] \quad \text{Equation S. 8}$$

The Value-based Resource Efficiency Indicator (VRE) is calculated by dividing the value of gross output (GO) by the value of non-sustainable inputs to the economy in relation to the product, such as energy, raw materials, and services, as shown in Equation S.9.

$$\text{VRE} = \frac{\text{GO} - S}{E + M} - 1 \quad \text{Equation S. 9}$$