Measuring Circular Economy

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Abstract The circular economy seeks its development through various efforts. Specific action guidelines and indicators are required for different levels, types of organizations, regions, etc. Likewise, diverse experiences are required to build indicators for each reality. A review of some indicators is made, and specific evidence is presented for each material or country. Future research is needed to test various indicators for their importance and validity.

Keywords Circular economy · Footprint · Waste · Plastic · Indicators · Index

1 Introduction

Globally, there is a growing trend for organizations to develop projects that enable the shift from linear economy to circular economy-based activities [17, 21]. In organizations based on linear economics, the processes performed by workers are based on the use of materials in one direction only, where the raw materials that enter the process are used to obtain the final product, the resulting waste is thrown away without any further action. However, under the circular economy approach, two fundamental components underpin the circular management approach: recovery and valorization of waste. These approaches imply that particular materials can be reused in the supply chain. Several countries are already initiating the regulation and promotion of circular activities such as Vietnam [25], Canada [9], Russia [78], Latin America

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A. Alvarez-Risco et al. (eds.), *Circular Economy*, Environmental Footprints and Eco-design of Products and Processes,
https://doi.org/10.1007/978-981-19-0549-0_1

[85], New Zealand [58], Bolivia [15], Ghana [5], and others. The European Union [99] and China [14] are leading the way to implement the circular economy.

In the scientific literature, there are several reports, ranging from correlational or descriptive models to descriptive [44] or correlational models [2], but there is very little publication associated with measuring circularity, which is critical to monitoring implementation progress.

2 Measure of Circular Economy

When thinking about indicators, one needs to recognize the efforts that can be made to achieve monitoring and eco-efficient use at different levels. The first component that requires monitoring is electricity. Table 1 shows the different indicators that can be applied at different levels. By the eco-innovation action plan of the European Union [13], there are different indicators (Table 1).

Table 1 Indicators based on sustainable resource management, societal behaviors, and business operations

Type of indicators	Source
Sustainable resource management	
Material footprint	https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Material_flow_accounts_statistics_-_material_footprints
Resource productivity	https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Resource_productivity_statistics
Trends in the repair sector	https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_1a_se_r2&lang=en
Extended producer responsibility	https://circulareconomy.europa.eu/platform/sites/default/files/ecopreneur-circular-economy-update-report-2019.pdf
Recycling rates in Europe by waste stream	https://www.eea.europa.eu/data-and-maps/indicators/waste-recycling-1/assessment-1
Municipal solid waste	https://ec.europa.eu/eurostat/databrowser/view/env_wasmun/default/table?lang=en
Recycling of packaging waste	https://ec.europa.eu/eurostat/web/products-datasets/product?code=ten00063
Recycling of biowaste	https://ec.europa.eu/eurostat/cache/metadata/en/cei_wm030_esmsip2.htm
Recycling of construction	https://ec.europa.eu/eurostat/databrowser/view/cei_wm040/default/table?lang=en

(continued)

Table 1 (continued)

Type of indicators	Source
Municipal waste recycled	https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Municipal_waste_statistics
Societal behaviors	
Citizens who have chosen alternatives to buying new products	https://data.europa.eu/data/datasets/s1102_388?locale=en
Coverage of circular economy	Scopus
Turnover in repair of computers and personal goods	https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Computer_and_personal_and_household_goods_repair_statistics_-_NACE_Rev._2
Number of enterprises and employment in repair of computers	
Number of countries of enterprises and employment in repair of computers	
Business operations	
Difficulties implementing circular economy	https://data.europa.eu/data/datasets/s2110_441_eng?locale=en
Financing sources for circular economy	
Availability of information	
Share of enterprises that facilitated recycling of products	https://ec.europa.eu/eurostat/cache/metadata/en/inn_cis9_esms.htm
Enterprises that extended product life	
Number of eco labeled products and services	https://ec.europa.eu/environment/ecolabel/facts-and-figures.html

3 OECD Indicators

Another indicator relevant to consider is the circular economy indicator proposed by the OECD. The most critical indicators are presented below by category type, sector, indicator, unit of measurement, and source.

Specifically, Moraga et al. [56] described indicators such as self-sufficiency for raw materials, green public procurement, waste generation, food waste, recycling rates, recovery for specific waste streams, the contribution of recycled materials to raw materials demand, trade-in recyclable raw materials, private investments, jobs and gross value added, and patents related to recycling and secondary raw materials. Other authors have proposed different indicators such as Geng et al. [22] (Table 2), Smol et al. [91] (Table 3), and De Pascale et al. [70] (Table 4).

Also, it is recommended to review the proposal of indicators and footprints by Saidani et al. [83], Huysman et al. [31], de Oliveira et al. [65], Padilla-Rivera et al. [66], Rincón-Moreno et al. [79], Avdiushchenko and Zając [4], and Cayzer et al. [8]. More specifically, it is relevant focus on longevity and circularity [16], eight historic port cities [24], indicators in plastic, textile and electro-electronic cases [82], use of energy accounting method [87], material circularity and life cycle indicators [27, 30, 50, 55, 61, 75, 94, 103, 105], manufacturing network [37, 52], product families

Table 2 Indicators based in Geng et al. [22]

Calculation formula	Unit
Output of main mineral resource = GDP/total consumption of main mineral resource	10,000 U/ton
Output of energy = GDP/energy consumption	10,000 U/ton sce
Energy consumption per unit of GDP = energy consumption/GDP (unit: ton sce/10,000 U)	ton sce/10,000 U
Energy consumption per added industrial value = industrial energy consumption AVI	ton sce/10,000 U
Energy consumption of key industrial product = energy consumption of steel (copper, aluminum, cement, fertilizer, paper)/steel production	ton sce/ton
Water withdrawal per unit of GDP = total amount of water withdrawal/GDP	10,000 m^3/U
Water withdrawal per added industrial value = amount of industrial water withdrawal/AVI	10,000 m3/U
Water consumption of key industrial sector product = total amount of fresh water consumption/total amount of steel production	108 m^3/ton
Coefficient of irrigation water utilization = actual amount of irrigation water consumption/total amount of irrigation water consumption	
Recycling rate of industrial solid waste = (industrial solid waste integrated utilization Q/industrial solid waste generation) 100%	

Table 3 Indicators based in Smol et al. [91]

CE–Eco-innovation inputs	*Unit*
Regional authorities environmental and energy R&D for CE appropriations and outlays	% of GDP
Regional total value of green early stage investments	EURO per capita
CE–Eco-innovation activities	*Unit*
Firms having implemented CE–eco-innovation activities aiming at a reduction of material input per unit output	% of total firms in region
Firms having implemented CE–eco-innovation activities aiming at an increase of material recycling	% of total firms in region
CE–Eco-innovation outputs	*Unit*
Generated industrial waste	Amount of waste/person
Generated municipal waste	Amount of waste/person
Recycled industrial waste	Amount of waste/person
Recycled municipal waste	Amount of waste/person
Life cycle assessment of enterprises activity	Amount companies with LCA reports per regions
Number of companies with “zero waste” program	

(continued)

Table 3 (continued)

Resource efficiency outcomes	*Unit*
Material productivity	Regional GDP/domestic material consumption of region
Water productivity	Regional GDP/water footprint of region
Energy productivity	Regional GDP/gross inland energy consumption of region
GHG emissions intensity	CO_2e/regional GDP
Socio-economic outcomes	*Unit*
Employment in eco-industries and circular economy (% of total employment across all companies of region). Revenue in eco-industries and circular economy (% of total revenue across all companies of region)	% of total revenue across all companies of region
GHG emissions intensity	(CO_2e/regional GDP)

Table 4 Indicators based in De Pascale et al. [70]

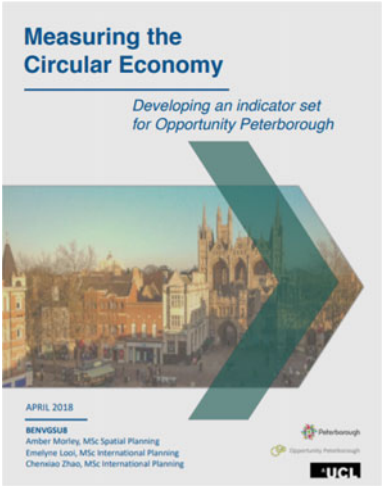
Micro-level	Meso-level	Macro-level
Disassembly Effort Index	Energy-based Indices	Multi-scale integrated analysis of societal metabolism
End-of-Life Index	Resource Productivity	A comprehensive index of circular Economy
Reuse Potential Indicator	MEP Indicators System	Super-efficiency DEA model
Material Circularity Indicator	Best-Worst Method	CE monitoring framework
Recyclability Benefit Rate	Evaluation Index System	Regional indicators of eco-innovation
Longevity Indicator	Resource Productivity Indicator	Index system for evaluating the circular economy development
Material Reutilization Score	Eco-Efficiency Indicator	Circularity indicators based on the MFA approach
Recycling Indices	Wastewater Circonomics Index	The evaluation index system of circular economy development level

[49], cultural heritage buildings [18], BWM-DEMATEL approach [108], levels of innovation [42], waste [53, 54, 74, 77, 86, 92], relation with sustainability [37, 40, 47, 80], standard BS 8001:2017 [71], agriculture [72, 100], city level [1, 26, 39, 60, 67, 68, 88], alternative methods [10, 45, 11, 20, 33, 35, 36, 51, 62–64, 69, 76, 81, 84, 101, 102], in companies [34], plastic [32, 93], mobile phones [19], and supply chain [7]. Also, there is evidence of indicators by regions or countries such as Germany [29], China [14, 23, 48, 95, 106–107], Sweden [28], Croatia [43], and European Union [6, 46, 89, 90, 96, 97, 104] (Table 5).

Table 5 Indicators' contribution according to Kristensen and Mosgaard [41]

Indicator	Contribution
Disassembly Effort Index	Academic
Remanufacturing Product Profiles	Academic
Circular Economy Toolkit	Practical
End-of-life Index	Academic
Reuse Potential Indicator	Academic
Circular Economy Index Material Circularity Indicator	Practical
Circularity Calculator	Practical
Eco-cost/Value Ratio	Academic
Longevity Indicator	Academic
Material Reutilization Score	Practical

Some reports must be reviewed to obtain global information to develop successful strategies.



Source Morley et al. [57]

Source Tully [98]

Source Potting et al. [73]

Source Natural Scotland [59]

Source America's Plastic Makers [3]

Source European Circular Economy Stakeholder Platform [12]

Closing Remarks

In these times of the COVID-19 pandemic, resilience must be based on the eco-efficient use of materials and, therefore, requires building fundamental indicators to help monitor. The book presents the specific development of footprint certifications, focused on different materials. The evidence presented in this chapter should be used as inputs for future research to be carried out, testing the indicators from the governmental, business, and citizen point of view.

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