ECOLOGICAL INDICATORS

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Abstract

In a transition to a more circular economy, the monitoring of trends and patterns is key to understanding how the various elements of the circular economy are developing over time. For this, performance indicators are needed. The previously applied indicators focus on the waste management system include collection and recycling rates. Similar to these indicators, new performance measures for Circular Economy have been formulated, such as the Circularity Indicator. All of these, however, represent mass-based indicators and do not cover an environmental dimension. As the ultimate goal of the transition from a linear to a circular economy should be a reduced environmental impact, policies should incorporate concepts like life cycle assessment into their target system to facilitate an environmental improvement of the system.

Introduction

The circular economy action plan (EC 2015) describes the circular economy as an economy '*where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized'*. In the transition to a more circular economy, the monitoring of trends and patterns is key to understanding how the various elements of the circular economy are developing over time. The circular economy action plan of the European Commission (EC 2015), therefore, includes targets for the recycling and re-use of materials to increase waste management's contribution to a circular economy. The results of monitoring should form the basis for setting new priorities towards the long-term objective of a circular economy. They are not just relevant to policy makers, but should inspire a wider public and drive new actions. To assist in long-term monitoring and effective comparison among states and regions, however, harmonized indicators are essential.

With regard to anthropogenic resources, the stocks and flows of materials created by humans or caused by human activity, recycling rates are the indicators most often used for monitoring purposes. Recycling rates are, however, often not well-defined and can describe various performance measures, from collection to recycling rates (Haupt et al. 2017). To facilitate the comparison of waste management systems of member states, European countries have recently harmonized the performance measure for describing inputs to recycling processes instead of harmonizing collection system rates. The amount of collected and sorted material is therein set in relation to the amount of material consumed, which is equivalent to the intermediate recycling rate shown in Figure 1 (Haupt et al. 2017).

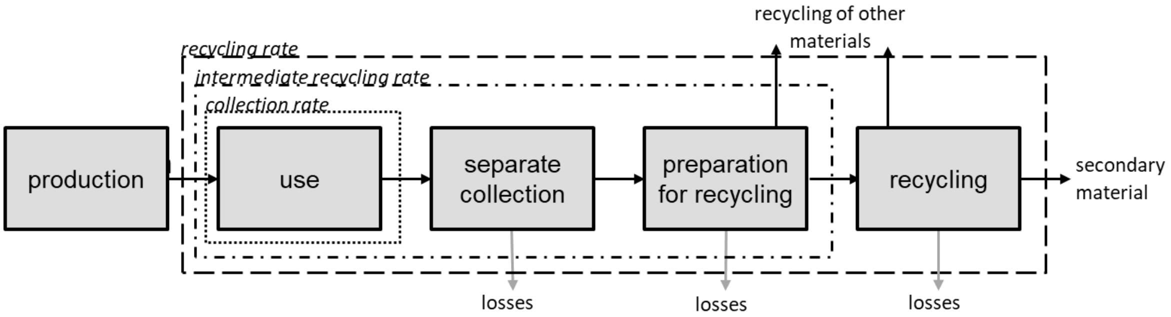

Figure 1: Schematic representation of waste management system with indicated collection, intermediate recycling and recycling rate. The intermediate recycling rates is equal to the recycling rate proposed by the European Commission.

Although the common definition proposed for all European countries makes the assessed rate more useful, intermediate recycling rates still neglect material losses and material quality in the recycling processes and therefore neglect indicators which could provide incentives to increase the efficiency of recycling. For example, non-packaging glass mixed in with household's glass recycling would increase the collected and sorted input into recycling processes and thereby increase the recycling rates. However, non-packaging glass can be detrimental to the secondary material quality and might lead to decreased secondary material availability. To consider these losses, recycling rates that include a measure of recycled material outputs are instead proposed as an indicator. Recycling rates can be further used to compare the waste management performance of different countries as they include the recycling process and, therefore, provide incentives to optimize all processes. In addition, they provide information about secondary materials produced from waste and hence include the full product system.

A new indicator for Circular Economy?

The more traditional material flow analysis-derived indicators presented above need to be supplemented with indicators and frameworks of indicators to measure the transition towards a Circular Economy and to monitor the shift in economic systems. Recent activities in this direction are described below, with a focus laid on indicators around waste management.

The Ellen MacArthur Foundation proposes a Circularity Indicator, covering not only the end-of-life phase of materials, but also the material production process as well as the product's use phase. In the production process, the input from virgin and recycled materials is analyzed. Comparing the duration of the use phase among similar types of equipment should then reveal insights into the durability of products and repair and maintenance schemes. The waste treatment is included as a recycling rate, using secondary materials as a point of measurement. The indicator focuses only on technical cycles and materials from non-renewable sources as these systems are better understood. The Circularity Indicators can be used at a product and a company level and can be complemented with indicators on energy usage and CO2 emissions. (Ellen MacArthur Foundation 2015)

Similarly, the European Commission has put forward a framework for monitoring the progress towards a Circular Economy, consisting of 10 indicators and divided into 4 groups: i) production and consumption, ii) waste management, iii) secondary raw materials, and iv) competitiveness and innovation. While the framework comprehensively assesses influencing factors and material flows in or around a circular economy, it lacks environmental performance indicators, even though moving towards a more sustainable system is often mentioned as an opportunity to reduce the environmental impacts of society. (European Commission 2018)

China implemented Circular Economy policies as early as 2003 and developed a framework to measure its progress. The framework includes a wide range of indicators on economy and resource efficiency that can be clustered into four groups: (i) resource output rate, (ii) resource consumption rate, (iii) integrated resource utilization rate, and (iv) waste disposal and pollutant emissions (Geng et al. 2012). These indicators include measures on energy, water and material consumption as well as emissions released into the environment. Although lacking a life cycle perspective, the Chinese framework incorporates the environmental dimension of circular economy. Carbon reduction and other ecological indicators are part of the low-carbon economic development project in China (in place since 2010) and are therefore not directly included among the circular economy indicators (Geng et al. 2012). In addition, an emergy[1]-based indicator was proposed by Chinese researchers to also measure up- and downstream impacts of consumption (Geng et al. 2013), which has been applied in some Chinese case studies.

Comparing all previously proposed indicators, the question remains whether the primary goal of the circular economy with regard to material recycling is the supply of alternative resources from secondary sources to minimize primary resource use or the minimization of environmental impact. In the former case, the recycling rate is a good performance indicator. If lowering environmental impacts is the primary goal, detailed assessments of the various recycling processes are needed, including the modelling of substitution and the associated displacement effects (Haupt et al. 2018; Geyer et al. 2015; Zink et al. 2015). Measuring environmental impacts can be completed through use of a life cycle assessment; however, this is more data intensive than a pure material flow analysis but provides a broader perspective and is therefore key for an environmentally optimal waste management system. While today's metrics often focus only on the closing of material cycles, the Waste Framework Directive of the European Union requests the application of life cycle assessment to identify cases in which it is reasonable to deviate from the classical waste hierarchy (avoid, reuse, recycle, recover, and landfill; EC 2008). Using the current indicators, however, environmental benefits and impacts remain unaddressed.

Improving mass-based indicators for waste management systems

A mass-based indicator, such as a recycling rate that considers all processes up to the secondary material (Figure 1), allows resource efficiency to be assessed from a holistic perspective, taking consumer behavior, material purity and recycling efficiency into account. For this reason, the indicator is recommended for mass-based national statistics. Ideally, the recycling rate can be broken down to assess process-specific improvement potentials within the collection, sorting and recycling processes of the material. A potential obstacle for the implementation of recycling rates as an indicator is the need for industrial data on process efficiencies and secondary markets.

In addition to recycling rates, the distinction between closed-loop and open-loop recycling pathways can help to identify the material circularity, as shown in a comprehensive study on the Swiss recycling system (Haupt et al. 2017). Closed-loop recycling describes recycling schemes in which the process maintains the original material quality to an extent that later integration into the same product is feasible. A circular economy is based on a high level of closed-loop recycling, i.e. the reversibility of material usage. To monitor material circularity, it is therefore recommended to extend the pure mass-based recycling rate with a quality perspective and include information on closed-loop or open-loop

[1] Definition of emergy (Geng et al. 2013): "Emergy assigns value to nature's environmental effort and investment (e.g., solar, deep geothermal heat, and gravity) to make and support flows, materials, and services and to contribute to the economic system. Given that solar energy is the dominant energy input to Earth, emergy expresses all inputs and flows in solar-equivalent Joules (seJ), a critical feature that enables distinctions between qualities of resources."

recycling systems. This requires, however, considering the recycling process when monitoring end-of-life treatments.

Although the classification into closed-loop and open-loop recycling provides an indication of material circularity and recovered material quality, it should not be expected to correlate to the net environmental benefit (Geyer et al. 2015; Haupt et al. 2018). For example, the recycling of glass into insulation material leads to environmentally higher credits than the production of packaging glass (Haupt et al. 2018).

Indicator framework to monitor a Circular Economy

If targeting a reduced environmental impact with the realization of a circular economy, the need for an impact-based indicator becomes obvious (e.g. Pauliuk (2018) and Haupt et al. (2017)). However, there have been few initiatives to incorporate life cycle assessment in indicators for Circular Economy. The first initiatives to do so include the emergy indicator discussed in China (Geng et al. 2013), the indicator dashboard outlined in Pauliuk (2018), and the Circular Economy Performance Indicator (CPI) proposed by Huysman and colleagues (2017). The latter measures the actual obtained environmental benefit (i.e. of the currently applied waste treatment option) over the ideal environmental benefit according to quality for this flow. These indicators, however, have not been applied on a large scale.

There are several prerequisites to a new indicator being used in national target systems, for international comparison and for the information of consumers and stakeholders. The following criteria as defined by Oswald (2013) cover all aspects identified above. The indicator should (i) be useful, i.e. should be tailored to the objective and (ii) link to existing policy objectives. If the primary objective of circular economy is the minimization of environmental impacts through using wastes as a resource, the indicator needs to reflect not only the environmental benefits and burdens in recycling, but also of remanufacturing and repair. To ensure usability, the indicator must also allow for fraction-specific targets. As targets on the performance of the waste management system are used to support decisions in policy making and to inform consumers, the indicator is required to be (iii) easy to use and communicate. Furthermore, the indicator should be (iv) comparable (between different time periods and also across geographical entities) by means of a consistent definition of system boundaries. To operationalize the use of an indicator, it needs to be (v) feasible in terms of data input.

Ideally, an indicator should also be diagnostic in the sense that it enables the identification of cause-effect relationships, resulting in different metric values. While mass-based indicators allow for some cause-effect relationships, they do not allow environmental performance to be set in relation to waste management strategies. Therefore, there is a need for a mass-based indicator to assess and evaluate, for example, the sorting behavior by consumers and the recycling-process efficiency, as well as an impact-based indicator providing information on the environmental performance of material recovery. The use of a combined indicator framework encompassing mass-based and impact-based indicators would enable a closer monitoring of movement towards Circular Economy. Below, the important criteria for both types of indicators are given.

In addition to mass-based indicators, impact-based indicators should be developed to assess waste management systems when moving towards a Circular Economy. The established target system should be material specific to enable for the formulation of meaningful targets for individual industries and consumers. As Haupt et al. (2018) confirm, the environmental performance of an integrated waste management system largely depends on the use of the secondary material, i.e. the resulting credits from substitution. Therefore, the market for recovered materials needs to be taken into account. An impact-based target could be set as a share of the environmental impact caused in the production of consumed goods that should be recovered in the waste management system (Huysman et al. 2017).

This would result in aiming at a high environmental efficiency in the use-phase, sorting, and recycling. When analyzing the performance of integrated waste management systems, indicators could also express environmental savings per person and fractions for which the targets could be set according to personal environmental budgets. These limits may be deduced from the planetary boundary concept or other target systems. Impact-based indicators would also allow for priorities to be set according to the environmental importance of fractions (Haupt et al. 2018). For waste from electric and electronic equipment, for example, due to the mass-wise dominance of steel in such equipment, a focus on recycling the ferrous scrap instead of (environmentally) more valuable metals such as the rare earth elements (Oswald 2013) lead to lower environmental benefits than the recycling of the rare earth metals would entail. Compared to mass-based indicators, impact-based indicators consider the exchanges within the environment, auxiliary material, energy consumption, emissions as well as the quality and quantity of secondary resource availability. The substitution of primary resources is included in the environmental assessment assuming that high quality secondary materials are typically able to substitute for a larger range of products than lower quality material, for which application options are more reduced. To make substitution modelling and the results thereof more transparent and interpretable, the application of a reporting framework as proposed by Vadenbo et al. (2017) is recommended. Such a framework allows for transparent reporting on assumed recovery efficiencies and on the substitutability of the resources recovered compared to potentially displaced products, and also takes the expected changes in the consumption of competing products into account.

Final remarks

To provide guidance for future policymaking and to develop optimal waste management strategies, a holistic view on Circular Economy strategies is needed. The current performance indicators applied in waste management, however, are solely based on quantitative measures and do not consider the environmental impacts. The development of impact-based targets should therefore be fostered and integrated into Circular Economy actions.

Conclusions:

Based on the arguments above, the following conclusions can be drawn:

- Circular Economy indicators are so far mostly mass-based and do not cover an environmental dimension.
- Targeting a minimization of environmental impacts with circular economy requires an indicator for evaluating the environmental performance covering several possible environmental impacts.

Recommendations:

There are numerous mass-based impact categories. When applying these indicators, the system boundaries should be drawn according to the targets set. If the target is to measure the performance of waste management systems, a recycling rate also covering the recycling processes should be used to analyze the full improvement potential.

As the ultimate goal of the transition from a linear to a circular economy should be a reduced environmental impact, policies should incorporate concepts like life cycle assessment into their target system to facilitate an environmental improvement of the system.

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