Circular economy in companies: an analysis of selected indicators from a managerial perspective

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INTRODUCTION

In recent years, the circular economy (CE) concept has gained increasing attention worldwide. It has been widely explored by researchers as a promising path to sustainable development. However, the implementation of CE principles is not an easy task. It requires accurate tools to support decision-makers in setting adequate goals and monitoring the effects of actions undertaken to move from the linear to the circular model. Therefore, increasing attempts to develop circularity indicators have been noticed in the last few years (Saidani et al., 2019). However, the research on CE indicators measuring the application level of CE strategies is still in its early phase and there is a strong need for studies on effective CE performance evaluation, at the micro level in particular (Elia et al., 2017). This article presents a comprehensive analysis and comparison of CE indicators available at the micro level. It aims to recognize their usefulness for practical CE implementation in companies. Therefore, using managerial perspective, it focused on each metric suitability for a comprehensive evaluation of CE performance and its potential to support the decision-making process in this area.

CONCEPT OF CIRCULAR ECONOMY

The circular economy (CE) concept has become popular in recent years as a model which links the environment and economics. The term "circular economy" was used for the first time, by Pearce and Turner in 1990, but the concept itself was described much earlier (in 1966) by Kenneth Boulding in the essay "The Economics of an Approaching Spacecraft Earth" (Heshmati, 2015). Since that time many CE definitions have been developed and many articles reviewing the CE definitions have been written (e.g. Kirchherr et al., 2017). According the most popular definition developed by the Ellen MacArthur Foundation CE is "an economic and industrial model that is restorative and regenerative by design (...) and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles" (Ellen MacArthur Foundation, 2012). Korhonen et al. defined the CE as "a sustainable development initiative with the objective of reducing the societal production-consumption systems' linear material and energy throughput

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flows by applying materials cycles, renewable and cascade-type energy flows to the linear system. This definition promotes high-value material cycles alongside more traditional recycling and develops systems approaches to the cooperation of producers, consumers and other societal actors in sustainable development work" (Korhonen et al., 2018).

As above mentioned definitions show, the aim of CE concept is to consistently maintain the highest value and usability of products and components during their life cycle through changing the linear loop of material flows ("Take – Make – Dispose") to a circular loop ("Take – Make – Re-use") (Janik and Ryszko, 2017). The transition from a linear to a closed economy requires the fulfillment of three basic principles: (1) preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows, (2) optimize resource yields by circulating products, components, and materials at the highest utility at all times and (3) foster system effectiveness by revealing and designing out negative externalities (Ellen MacArthur Foundation, 2012).The implementation of these principles is only possible if the product is designed and optimized for circularity and it can be disassembled and reused. In the literature on circular economy, a distinction is made between various options for circularity, which are described as the model of 3Rs, 4Rs or even 9Rs frameworks. These all options are as follows:(1) Refuse -preventing the use of raw materials; (2) Reduce - reducing the use of raw materials;(3) Reuse -re-use by another consumer of product (i.e. second-hand, sharing of products);(4) Repair: maintenance and repair of defective product; (5) Refurbish - restoring an old product and bringing it up to date; (6) Remanufacture -using parts of discarded product in a new product with the same function; (7) Repurpose -using discarded product or its parts in a new product with a different function; (8) Recycle - processing and reuse of materials; and(9) Recover - Incineration of materials with energy recovery (Potting et al., 2017). It has to be noted that in order to increase the transparency of the analysis, this article is based on the 4R model covering such activities as: Reduce, Reuse, Recycle and Recover.

The shift to a circular economy requires companies to rethink not only the use of resources but also to redesign and adopt new business models based on dematerialization, longevity, refurbishment, remanufacturing, capacity sharing, and increased reuse and recycling. This requires the use of appropriate tools and indicators that make it possible to measure the level of application of CE principles and to justify the actions aiming to ensure the transition from linear to circular economy. The micro level activities and relevant metrics are of particular importance.

CIRCULAR ECONOMY INDICATORS – TAXONOMIES AND CLASSIFICATION CRITERIA

The efficient implementation of CE principles requires suitable tools to support policy-makers and decision-makers in setting adequate goals and monitoring the effects of CE adoption. In recent years, numerous CE indicators have been developed, but there is inconsistency concerning their purposes, scopes, and potential application.

There are few classifications of tools and indicators related with the CE characteristics, focused on assessment, improvement, monitoring and communication on the CE performance. To the best of our knowledge, the most comprehensive analyses of CE indicators have been performed by Elia et al. (2017),

Parchomenko et al. (2019), and Saidani et al. (2019) so far.
Elia et al. (2017) reviewed 17 index-based environmental assessment methodologies and proposed a four-levels framework introduced for supporting measurement of the CE paradigm adoption. These outlined levels comprise:

– processes to monitor (i.e. the material input, the design, the production, the consumption, the end-of-life resource management),
– actions involved (i.e. circular product design and production, business models, cascade/reverse cycle skills, cross cycle and cross sector collaboration),
– requirements to be measured (i.e. reducing input and use of natural resources, reducing emission levels, reducing valuable materials losses, increasing share of renewable and recyclable resources, increasing the value durability of products),
– implementation levels of the CE paradigm (i.e. the micro level – referring to single companies or customers, the meso level –eco-industrial parks and the macro level – from cities to nations).

The taxonomy proposed by Elia et al. (2017) used two factors: the index-based method typology (i.e. a single synthetic indicator or set of multiple indicators divided in several categories) and the parameter(s) to be measured (i.e. material flow, energy flow, land use and consumption, and other life cycle based). In addition, they identified 16 index methods intended to assess CE strategies performance which were categorized according to the field of implementation levels of the CE paradigm. In relation to this categorization, at the micro level, the Material Circularity Indicator (MCI), the Circular Economy Index (CEI) and the Reuse Potential Indicator (RPI) were pointed out. Based on Multiple Correspondence Analysis (MCA), Parchomenko et al. (2019) analyzed 63 CE metrics and 24 features relevant to CE. The MCA was used to determine how the different CE features are related with CE metrics (i.e. indicators, scoreboards, assessment tools, etc.).This resulted in identification of the following main groups of CE metrics:

– a resource-efficiency cluster, related with CE features such as: wastedisposal, primary vs. secondary materials, parts and products, resource productivity or process efficiency, recycling efficiency, and energy consideration. The exemplary metrics in this cluster include, inter alia, the Resource Efficiency Scoreboard, the Raw Materials Scoreboard, the Cumulative Exergy Extraction from the Natural Environment, Input-Output analysis metrics, the Economy-wide material flow analysis, the Indicator for the support of investment decisions, the Zero-waste-index, and LCA-based metrics;
– a materials stocks and flows cluster, related with CE elements such as: destination of flows, waste disposal, stock availability or concentration, downcycling and quality loss, cascading use, and potential for recycling or remanufacturing. The exemplary metrics in this cluster were dominated by Material Flow Analysis-related metrics,
– a product-centric cluster, related with CE elements such as: product, part, material retention, longevity or residence time. The exemplary metrics in this cluster were focused on product related metrics, i.e. the Longevity indicator, the Longevity-circularityindicator, the Circular Economy Indicator Prototype, the Circular Economy Toolkit, and the Materials Circularity Indicator(however, this metric combines multiple elements of all three identified clusters).

Saidani et al. (2019) identified 55 CE indicators and developed comprehensive taxonomy of CE metrics based on the following 10classification criteria:

- level of CE implementation (i.e. micro - organization, products, and consumers, meso – symbiosis association, industrial parks, and macro – city, province, region or country),
- CE loops (i.e. maintain/prolong, reuse/remanufacture, recycle),
- performance (i.e. intrinsic circularity, consequential circularity),
- perspective of circularity (i.e. actual, potential),
- possible uses (i.e. information purposes, decision-making purposes, communication, learning),
- degree oftransversality (i.e. generic, sector-specific),
- dimensionality (i.e. a single number, multiple indicators),
- measurability (i.e. quantitative, semi-quantitative, qualitative),
- format of the assessment framework (i.e. formulas to compute manually, computational tool),
- development background and origins (i.e. academics, companies, agencies).

With regard to the CE implementation level, 20 CE indicators available at the micro level, 16 CE indicators at the meso level, and 19 CE indicators at the macro level were identified. The analyzed CE indicators available at the micro level include, inter alia, Closed Loop Calculator, Circular Economy Index, Circular Economy Indicator Prototype, Circular Economy Performance Indicator, Circular Economy Toolkit, Circularity Index, Circularity Potential Indicator, Input-Output Balance Sheet, Material Circularity Indicator, Recycling Rates, and Reuse Potential Indicator. It must be noted that the CE metrics comprising environmental, economic and social issues which allow setting appropriate goals and supporting decision making are of the utmost importance. This concerns, in particular, CE indicators at micro level focused on development and assessment of effective CE strategies in companies. However, research on these indicators and methodologies is still in the early phase. Nevertheless, companies need to understand how to transform information given by CE indicators into specific actions or practical recommendations and to recognize the relevance and potential benefits of CE indicators to guarantee their successful implementation in the strategic and operational management.

ANALYSIS OF CIRCULAR ECONOMY INDICATORS AT THE MICRO LEVEL - RESEARCH METHODOLOGY

The research method employed in this article was based on a systematic literature review. The identification of CE indicators at micro level started with the search of articles, conference papers, studies and reports on CE via Web of Science, Scopus and Google Scholar. Different options of the query wording were used for the database search in title, abstract and keywords fields. These wordings included: ‘circular economy’, ‘circularity’, ‘assessment’, ‘evaluation’, ‘measure’, ‘tool’, ‘indicator’, ‘index’, ‘indices’, ‘metrics’, ‘micro‘, ‘company‘, ‘product‘, and ‘material‘.

In the next step, all relevant references related to the identified CE indicators were analyzed in order to explore CE indicators characteristics, formulas, data requirements and possible applications. In order to facilitate comparison of CE indicators different aspects have been captured by criteria focused on managerial issues and practical applications. The established assessment criteria reflected parameters related to needs and expectations of decision-makers, entrepreneurs and industrial practitioners. These criteria have been also proposed to distinguish advantages and disadvantages of particular CE indicators. Based on literature review (Baran et al., 2016; Elia et al., 2017; Kirchherr et al., 2017; Saidani et al., 2019), 11 categories and relevant characteristics have been identified for comparison. These categories and characteristics comprise:

I. Criteria related to analytical opportunities and potential application of CE indicators:
   - CI-1. Core 4R framework embracing 4R principles, i.e. reduce, reuse, recycle, recover;
   - CI-2. Sustainable development components, i.e. economic, environmental, social;
   - CI-3. Determination of indicator based on life cycle perspective, i.e. material sourcing, production, consumption/use, end-of-life/disposal;
   - CI-4. Complexity of analyzed aspects, i.e. input and use of natural resources, emissions levels, valuable materials losses, share of renewable and recyclable resources, product durability;
   - CI-5. Application level, i.e. material, component, product/service;
   - CI-6. Dimensionality, i.e. single indicator, multiple indicators;
   - CI-7. Format, i.e. textual formulas to compute, computational tool, web-based tool;

II. Criteria related to organizational and operational issues of practical application of CE indicators:
   - CII-1. Time consumption of adequate indicator application;
   - CII-2. Scope and detail of the required data;
   - CII-3. Required specialized knowledge and competence to apply indicator;
   - CII-4. Supporting the decision-making process.

As regards the first group of the criteria, relevant characteristics were confirmed for particular CE indicators only if related issues are determined explicitly. As for the second group, 5-level scales were used with the following rates: very low, low, medium, high and very high. In the case of criteria CII-1 - CII-3 the lower the rating the more attractive feature is available. Considering criterion CII-4 the higher the rating the more desirable feature is accessible.

The assessment was carried out according to the Delphi methodology assumptions in three rounds. Firstly, each expert made individual evaluations. Then all evaluations were collected and aggregated and the results of CE indicators comparison were forwarded to each panelist for an eventual verification. Lastly, the final results of the evaluation were determined during the joint meeting and discussion of experts.

ANALYSIS OF CIRCULAR ECONOMY INDICATORS AT THE MICRO LEVEL – RESEARCHRESULTS

Based on a systematic literature review and exploration of relevant articles, conference papers, studies and reports on CE, 19 CE indicators available at micro level were found. The following indicators were analyzed in this research:

1. Circular Economy Indicator Prototype (CEIP) – a multi-measure approach based on a points-based questionnaire with 15 questions grouped according to product life cycle stages (i.e. design/redesign, manufacturing, commercialization, use, end of life) converged into a simple final result. It works better with tangible goods that are built from/assembled (not transformed) from other tangible goods where a comprehensive bill of materials is available (Cayzer et al., 2017).
2. Circular Economy Performance Indicator (CEPI) – defined as the ratio of the actual obtained environmental benefit (i.e. of the currently applied waste treatment option) over the ideal environmental benefit according to quality, the latter being the benefit of the waste treatment option to which the stream should be directed according to its composition/quality with a minimal required effort, assuming closed-loop recycling is better and incineration is less preferable (Huysman et al., 2017).
3. Circular Economy Toolkit (CET) – a '5 Minute Assessment Tool' which analyzes the products and services sold by a company to give guidance on potential improvement areas. It uses questionnaire covering 33 issues associated with product life cycle approach (i.e. design, manufacture and distribute, usage, repair/maintenance, reuse/redistribution, remanufacturing/refurbishment, product as a service, recycling at end of life) (Evans and Bocken, 2013).
4. Circular Pathfinder (CP) – a starting tool for companies interested in circular economy thinking, allowing them to explore and identify the most suitable circular pathways for their products by answering just a few questions. CP guides the user towards circular pathways that have potential in their specific case. It comprises qualitative guidance to 8 suitable or optional circular pathways: prolong, upgrade, reuse, repair, refurbish, remanufacture, recycle, biodegrade (ResCoM, 2017a).
5. Circularity Calculator (CC) – tool that helps designers to understand how strategic design decisions influence the degree of circularity of resource flows and potential value capture within the product-service-system. CC displays the potential mass and value flows of a product, based on whether the different parts are either reused, remanufactured and/or recycled. It allows modeling of different conceptual design solutions and business models to explore and compare design scenarios and their impact on overall circularity, recycling rate and value recovery potential (ResCoM, 2017b).
6. Circularity Index (CI) – based on multiplication of 2 simple ratios: α that describes the combined effects of stock dynamics and dissipative losses (i.e. relation of recovered end-of-life (EOL) material to total material demand) and β that describes quantity of energy required to recover material relative to the energy required for primary material production from virgin ore (Cullen, 2017).
7. Circularity Potential Indicator (CPI) – a guided questionnaire of 20 attributes desired for a circular economy based on a hybrid top-down – objective-driven and bottom-up – data-driven – approach including the four building blocks of CE defined by the Ellen MacArthur Foundation. CPI aims at evaluating the circularity potential of industrial products (during design, re-design or benchmarking phases) as well as providing keys for improvement and monitoring the circularity of products and businesses practices (Saidani et al., 2017).

8. Closed Loop Calculator (CLC) – indicator developed by the Kingfisher group that aims to measure how closely a product can be defined as “Closed-Loop.” CLC utilizes 10 important credentials of closed loop products as variables in its calculations aggregated to single indicator. Some of these credentials include material, ability to be rented or repaired, and if the product can be disassembled into component part or materials (Kingfisher, 2014).
9. Eco-Efficient Value Ratio (EVR) – an indicator calculating the eco-efficiency of a product and/or service as a ratio of eco-costs (the environmental burden generated by a product in the entire life cycle expressed in monetary terms) and value of products (the price that people are willing to pay for a product on the market). The calculation of EVR requires the expression of all environmental effects in monetary terms based on the costs what should be incurred to reduce environmental pollution and materials depletion to "no effect level" (Scheepens et al., 2016)
10. End-of-Life Recycling Rates (EoL-RRs) – an indicator measuring, for a given raw material, how much of its input into the production system comes from recycling of "old scrap" (i.e. scrap from end-of-life products). It is a percentage of a material included in EoL products that is separated and sorted to obtain recyclates returned to production processes of raw material or products manufacturing. It determines the scale of closing the circulation of a given material (Graedel et al., 2011).
11. Input-Output Balance Sheet (IOBS) – a tool that allows measuring the product or service circularity by calculating the input-output balance sheet covering the entire life cycle of the product. The assessment includes the circularity of the resources flow used in life cycle, the use of the materials and energy from renewable sources, recycled materials, frequency of reuse and sharing of the product and the materials intended for recycling, reuse or landfill. In addition, functional aspects such as energy efficiency, water use and environmental impact as well as the economic efficiency of the process need to be assessed (Capellini, 2017).
12. Material Circularity Indicator (MCI) – a tool developed by the Ellen MacArthur Foundation and the Grant Design aims to assess circularity at the product and the company levels and measure the reduction of input and use of natural resources, lost valuable materials and the growing share of renewable and recyclable resources and durability of the product value. It measures the extent to which the linear flow has been minimized and the circular flow maximized (Ellen MacArthur Foundation, 2015).
13. Material Reutilization Score (MRS - C2C) – an indicator used to quantify the material reutilization, which is one of criterions included in the Cradle to Cradle (C2C) Certified Product Standard addressing the recycling value of the materials. It quantifies the recyclability potential of a product considering two variables: the intrinsic recyclability (IR) of the product (i.e. the % of the product that can be recycled at least once after its initial use stage) and the % recycled content (RC) (C2C, 2016).

14. Product Circularity Indicator (PCI) – tool for assessment of the circularities arising along the lifecycle of a product fabricated with additive manufacturing technologies. It is calculated based on the circularity indicators for materials, circularity indicators for auxiliary resources and circularity indicator for energy and aggregated to obtain overall product-system level circularity (Angioletti et al., 2017).
15. Product-Level Circularity Metric (PCM) – a metric which focuses exclusively on circularity with regard to products' composition in terms of virgin and recirculated materials and the activities required to recirculate materials. It is calculated as the ratio between economic value of recirculated parts and the economic value all parts. It is assumed that the economic value should be estimated of on the basis of the cost-based method (Linder et al., 2017).
16. Recycling Indices (RIs) for the CE – a tool for visualization of the product recycling rate value, which contains two indicators: Recycling Index (RI) and Material Recycling Index (Material-RI). Material-RI expresses the recycling rate of individual elements that are parts of product. The weighted average of the presented individual recycling rates provides the basis for the total recycling rate as presented by the Recycling Index (RI). RI is visually presented analogously to the EU Energy Labels and it expresses the level of recycling efficiency taking into account the entire recycling system from dismantling to end-processing (Schaik and Reuter, 2016).
17. Resource Duration Indicator (RDI) – a longevity indicator, which measures a contribution to material retention in a product system based on the amount of time a resource is kept in use. Such retention is a mean to maximize resource exploitation in the same product system through product use and reuse, as well as materials recycling. The value of RDI is expressed in a unit of time as a sum of three components: initial lifetime of product (A), earned refurbished lifetime (B) and earned recycled lifetime (C). It can be applied to measure the impact of business decisions on the longevity of precious materials (Franklin-Johnson et al., 2016).
18. Reuse Potential Indicator (RPI) – an indicator measuring the usefulness of the material for reuse taking into account the technical capability of the materials to be reused in commerce. It is based on "resource-based paradigm" i.e. the perception of waste as a potential resource. The underlying idea of the RPI is to know where and how to reuse materials contained in products after using them. It is calculated as the ratio of the net marginal revenue obtained from the sale of processed materials minus disposal costs to the amount of a material that can be reused using available technologies (Park and Chertow, 2014).
19. Recycling Rates (RRs) – an indicator for the circulating behavior of materials, which measures the available secondary resources obtained in recycling processes. It is the ratio between recycled materials and waste generated. RRs are divided into closed- and open-loop recycling rates (RRs). In open-loop recycling the secondary material is not used in the same product as in the previous period of life, in close-loop recycling the secondary material is used in the same product (Haupt et al., 2016).

Table 1 presents the results of assessment and comparison of analyzed CE indicators.

Table 1
Comparison of analyzed CE indicators available at micro level

Criteria	CE Indicators																	
	CEIP	CEPI	CET	CP	CC	CI	CPI	CLC	EVR	EoL-RRs	IOBS	MCI	MRS-C2C	PCI	PCM	RIs	RDI	RPI	RRS
I. Criteria related to analytical opportunities and potential application of CE indicators																			
CI-1. Core circular economy principles																			
Reduce	•		•	•	•		•	•	•		•	•		•					
Reuse	•		•	•	•		•	•	•		•	•	•	•	•		•	•	
Recycle	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•
Recover	•	•	•	•	•	•	•	•			•	•		•					
CI-2. Sustainable development components																			
Economic			•		•		•		•		•	•			•			•	
Environment	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Social									•										
CI-3. Determination of indicator based on life cycle perspective																			
Material sourcing	•		•	•	•		•	•	•		•	•		•					
Production	•		•	•	•	•	•	•	•		•	•	•	•	•		•	•	
Consumption /use	•		•	•	•		•	•	•		•	•							
End-of-life	•	•	•	•	•	•	•	•	•	•	•	•	•			•		•	•
CI-4. Complexity of analyzed aspects																			
Input and use of natural resources	•		•	•	•	•	•	•	•		•	•		•					
Emission levels			•						•		•								
Valuable materials losses	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Renewable and recyclable resources	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•
Product durability	•		•	•	•		•	•			•	•					•	•	
CI-5. Application level																			
Material		•				•				•	•	•							
Component						•					•	•	•		•	•	•	•	
Product/ service	•		•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•
CI-6. Dimensionality																			
Single	•	•				•	•	•	•	•			•	•	•		•	•	
Multiple			•	•	•						•	•				•			•
CI-7. Format																			
Textual formulas		•				•			•	•			•	•	•	•	•	•	•
Computatio-nal tool	•						•	•			•	•							
Web-based tool			•	•	•														
II. Criteria related to organizational and operational issues of practical application of CE indicators																			
CII-1. Time consumption of adequate indicator application	High	Very high	Medium	Low	High	High	High	High	Very high	Medium	Very high	Very high	Medium	High	High	Medium	High	High	Medium

Table 1 (continued)
Comparison of analyzed CE indicators available at micro level

CII-2. Scope and detail of the required data	**High**	**Very high**	**Medium**	**Low**	**High**	**High**	**High**	**High**	**Very high**	**Medium**	**Very high**	**Very high**	**Medium**	**High**	**High**	**Medium**	**High**	**High**	**Low**
CII-3. Required specialized knowledge and competence	High	Very high	Medium	Low	High	High	High	High	Very high	High	Very high	Very high	Medium	High	High	Medium	High	High	Medium
CII-4. Decision-making process support	High	Medium	High	Low	Very high	Low	High	Medium	Medium	Low	Very high	Very high	Medium	Medium	Low	Low	High	Medium	Low

The results of the analysis show that all 4 core CE principles (4R) are taken into account only in 8 of the analyzed indicators(i.e. CEIP, CET, CC, CPI, CLC, IOBS, MCI and PCI).The other CE indicators under analysis focus on specific CE principles. The EVR indicator is the only one which comprises all components (i.e. economic, environmental, social) of sustainable development. With regard to the life cycle perspective considered in the determination of relevant indicators, the broadest viewpoint is included in CEIP, CET, CP, CC, CPI, CLC, EVR, IOBS and MCI. The greatest complexity of the analyzed aspects occurs in relation to determination of the CET and the IOBS. However, CEIP, CP, CC, CPI, CLC and MCI are also calculated based on a wide spectrum of features.
Three of the analyzed CE indicators could be applied at the material, the component and the product/service level (i.e. CI, IOBS and MCI). Almost all the indicators under consideration can be used to measure product circularity, the exceptions being the CEPI and the EoL-RRs indicators devoted exclusively to the material circularity assessment. Most of the compared metrics are expressed as single indicators. Some CE indicators could be calculated with the assistance of a computational tool (i.e. CEIP, CPI, CLC, IOBS and MCI) and some are in the form of a user-friendly web-based tool (i.e. CET, CP and CC).Considering the time consumption of adequate indicator application, the scope and detail of required data and the required specialized knowledge and competence, the biggest challenge is the application of the following indicators: CEPI, EVR, IOBS and MCI. However, the IOBS and the MCI have very high potential to support the decision-making process. With regard to this issue, according to the research results, entrepreneurs and decision-makers might also get strong support from the application of such indicators as CC, CEIP, CET, CPI and RDI.

CONCLUSION

The measurement of CE performance at different levels is one of the core contemporary challenge on the road to sustainability. This article presents a comprehensive analysis and comparison of CE indicators available at the micro level. Based on a systematic literature review, 19 such CE indicators were identified. The usefulness of these indicators for practical implementation in companies was determined from a managerial perspective, with particular emphasis on the possibility of supporting the decision-making process. The results of the analysis indicate that taking account of analytical opportunities and potential application of CE metrics, the most suitable indicators seem to be: IOBS, MCI, CET, CC, CEIP, CPI, CLC and CP. However, they differ significantly in the criteria related to organizational and operational issues of their practical application. For example, if applied, the IOBS and the MCI show very high potential for the support of the decision-making process but their application requires a lot of time, detailed data and specialized knowledge. This means that entrepreneurs and decision-makers in companies intending to apply CE indicators with the highest analytical opportunities and application potential may encounter significant organizational and operational obstacles. The choice of a specific indicator should depend on the company's needs and on the possibilities of the relevant indicator application. The comparison of CE indicators presented in this article is intended to facilitate such a choice. However, it must be noted that this study, although supported by the experience and knowledge of experts, is subjective, and prioritization of particular entrepreneurs may differ from the achieved results.

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Abstract. The circular economy (CE) concept is now gaining increasing attention and it is being widely explored as a promising path to sustainable development. CE implementation requires extensive activities needed for the transition from the linear to the circular model and suitable tools to support decision-makers in setting adequate goals and monitoring the effects of undertaken actions. Considering the need for research on effective CE performance evaluation, this article presents a comprehensive analysis and comparison of CE indicators available at the micro level. Based on a systematic literature review, 19 such CE indicators were identified. The indicators were assessed and compared using the Delphi methodology. The suitability of each metric for a comprehensive evaluation of CE performance was analyzed taking account of the criteria related to analytical opportunities and potential application of CE indicators, together with the criteria related to organizational and operational issues of practical application of CE indicators. The usefulness of CE indicators for practical implementation in companies was determined from a managerial perspective, with particular emphasis on supporting the decision-making process. The comparison of CE indicators presented in this article is intended to facilitate the choice of a specific metric depending on the company's needs and on the possibilities of its application.

Keywords: circular economy, circular economy indicators, micro level, company