Volume **12** / 2024 ISSN 2344-102X
Issue 2 / **June** 2024 ISSN-L 2344-102X

CIRCULAR ECONOMY MEASUREMENT TOOLS, CHALLENGES, AND GLOBAL STANDARDIZATION

Roman BAHNARU
Academy of Economic Studies of Moldova
bahnaru@ase.md
Elena HLACIUC
Stefan cel Mare University of Suceava 720229, Romania
elena.hlaciuc@usm.ro

Abstract
The circular economy promise to offer solutions and support to solve recent environmental challenges. But how to measure Circular Economy, and what is de facto the Circular Economy. Perhaps because until 2024 there was no standardized definition of the circular economy, the multitude of definitions created problems for the development of a ubiquitous circular economy at the global level, and at the governance level it created more confusion than clarity in the multitude of green, blue, ecological or sustainable economies. This article examines the role of the definition of circular economy for measuring the circular economy. By aligning measurement tools and approaches, ISO 59020 enables organizations to assess their circularity performance more consistently. The findings suggest that standardized definitions and methodologies are essential for improving transparency and driving the adoption of circular economy practices across sectors.

Keywords: *measuring; circular economy; ISO 59000; enabler; challenge.*

JEL Classification: Q5, O13

I. INTRODUCTION

Measuring is a key driver in the transition to the circular economy, but at the same time is the main challenge. And as we know - if you can't measure it, you can't regulate it and you can't improve it.

But what do we measure de facto? According to the latest scientific articles, there are 221 or even more definitions of the Circular Economy (Valls et al., 2022;.Kirchherr et al., 2023).

Global circularity is still declining even after the circular economy gained popularity. The amount of discussions, arguments, and publications on this subject has nearly tripled (x3) in the last five years, indicating a greater interest and awareness of circularity. (Circle Economy, 2024).

At the moment the global economy is only 7.2% circular, and from year to year it is worse. In 2018 the circularity rate was 9.1%, in 2020 – 8.6%, and now it has reached 7.2% (Circle Economy, 2023). And it is largely due to the fact that more and more materials are being extracted, reaching an amount of 104 billion tons in 2024 (see www. materialflows.net).

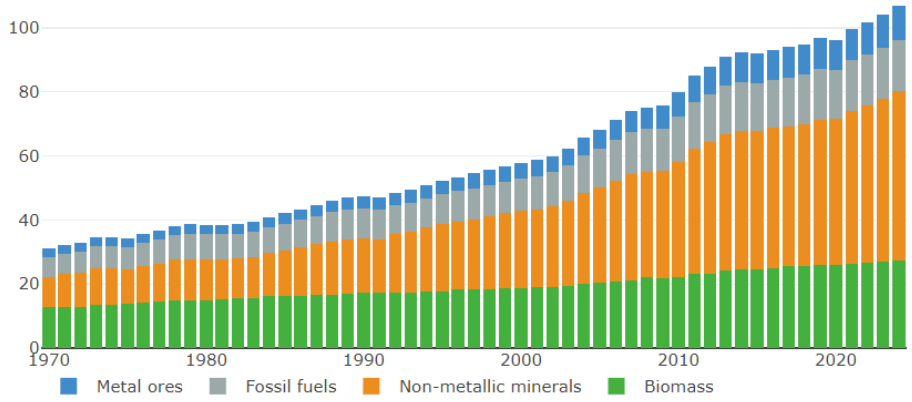

Figure 1. Material use 1970-2024, by material group

Source: https://www.materialflows.net/global-trends-of-material-use/

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Between 1970 and 2002, there was only a brief period of stagnation due to the fall of the former Soviet Union; after that, there was a period of considerable growth in material extraction. Non-renewable materials grew at exceptionally high rates, especially industrial and construction minerals (+429%). This is because, over the past few decades, minerals have been essential to meeting the demand for continuous infrastructure improvements in energy, transportation, and construction projects worldwide (see www. materialflows.net).

The countries of the European Union (EU) are world leaders in promoting the transition to the circular economy, having placed it centrally at the level of the economic growth strategy and embarking on a vast program of reform of the regulatory framework. The circularity rate for 2022 reached 11.5% in the European Union (Eurostat, 2023), the highest rate being recorded in the Netherlands (27.5%), Belgium (22.2%) and France (19.3%), and the lowest recycling rate is in Finland (0.6%), Romania (1.4%) and Ireland (1.8%).

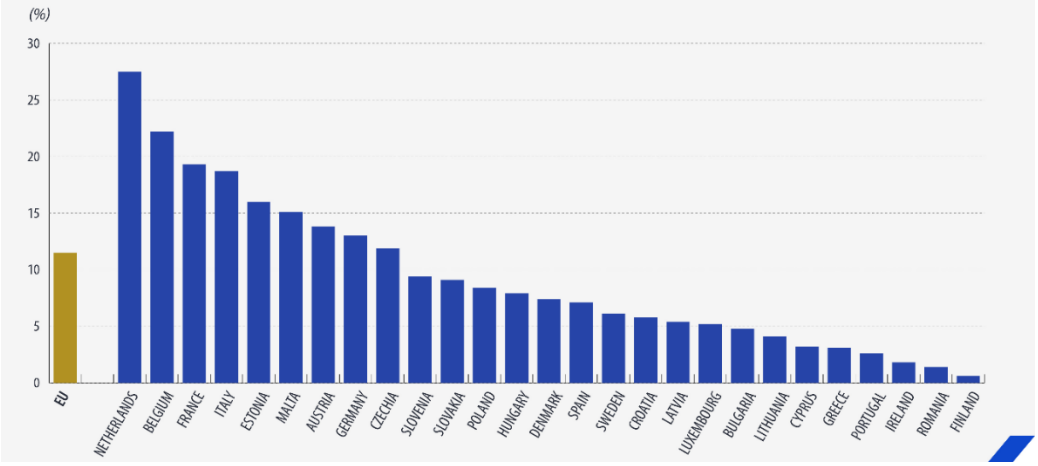

Figure 2. Circular material use rate in the EU (2022)

Source: https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20231114-2

In 2022, the highest circularity rate by main material type was metal ores, with 23.9%, followed by non-metallic minerals with 13.7%, biomass with 10.0%, and fossil/carrier energy materials with 3.2%.

The European Commission pledged to develop a straightforward and efficient monitoring system when it released the first EU Action Plan for the Circular Economy in December 2015. Two years later, on January 16, 2018, the European Commission published a Staff Working Document and a framework to track advancements in the circular economy. Ten indicators, some of which have subindicators, make up this monitoring framework, which covers a wide range of circular economy-related topics.

Due to the lack of unified methodology to measure the circularity at national level, a new metric was introduced by Eurostat – the Circular Material Use rate. Of course, the new indicator was consulted within working groups which include stakeholders in circular economy: environmental experts, national ministries, statistical agencies, civil society, research and academic institutions, etc. Their collaborative effort ensured the development of a comprehensive methodology to measure the transition for all EU countries to a more sustainable and circular economy. The contribution of recycled materials to total material use is measured by the circular material use rate.

Finally, the simplest method of estimating CE is the calculation of Circular Material Use (CMU) rate, even this is only one of the methods or indicators, which does not always take into account all processes related to CE. As mentioned above, it depends of course what we define by CE and the goals of measuring.

According to Eurostat's calculation method of the CMU rate (European Commission , 2018), the CMU rate measures the share of material recovered and fed back into the economy — thus saving extraction of primary raw materials — in overall material use. The indicator includes flows of materials but it does not include flows of water. The CMU rate is defined as the ratio of the circular use of materials (U) to an indicator of the overall material use (M):

$$CMU = \frac{U}{M} \quad (1)$$

Based on Eurostat methodology "numerator and denominator in equation 1 can be measured in different ways depending on considerations of analysis and data sources. The circular use of materials U in equation 1 can be approximated by the amount of waste recycled in domestic recovery plants and thereby indirectly or directly substituting primary raw materials. Recycled amounts of waste in treatment operations can be corrected by imports and exports of waste destined for treatment. Then, the CMU rate is formalised as following:

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$$CMU = \frac{U}{DMC+U} = \frac{RCV_R - IMP_W + EXP_W}{DMC+(RCV_R - IMP_W + EXP_W)} \quad (2)$$

With:
- DMC - domestic material consumption;
- RCV_R – recycling materials, based on Waste Directive/Law;
- IMP_W: amount of imported waste bound for recovery;
- EXP_W: amount of exported waste bound for recovery.

It might also have been feasible to view the CMU rate from a different angle than the one that Eurostat chose. The use of secondary material recovered from previous waste would be emphasized. This can also be considered a global contribution to reducing the extraction of primary raw materials (European Commission, 2018).

The imports and exports of secondary material recovered from former waste can be aggregated to net-imports of secondary material recovered from former waste.

$$CMU' = \frac{U'}{DMC+U'} = \frac{RCV_R + IMP_S - EXP_S}{DMC+(RCV_R + IMP_S - EXP_S)} \quad (3)$$

With:
- IMPs: amount of imported secondary material;
- EXPs: amount of exported secondary material.

The nation that uses the secondary material (recovered from former waste) receives the "credit" for its contribution to the global reduction of primary raw materials when the amounts of recycled waste in treatment operations RCV_R are adjusted by imports and exports of secondary material (RCV_R + IMPs – EXPs). This viewpoint appears to be more in line with the logic of national accounts, where the majority of re-attributions are focused on final use.

During the May 2017 meeting of the Eurostat working group on Environmental accounts, the group deemed both the alternative CMU' rate and the retained perspective for CMU rate to be reasonable and significant. The first option was finally chosen and, therefore, used by Eurostat to determine circularity rate in EU in general, and for each country. The CMU rate indicator is closely related to Sankey diagrams of material flows which play an important role in the monitoring framework for the circular economy (Eurostat, 2022).

Since the amount of recyclable materials used in the production process must be known, as shown in equation 2 and *Figure 3*, calculating the circularity rate is not an easy task.

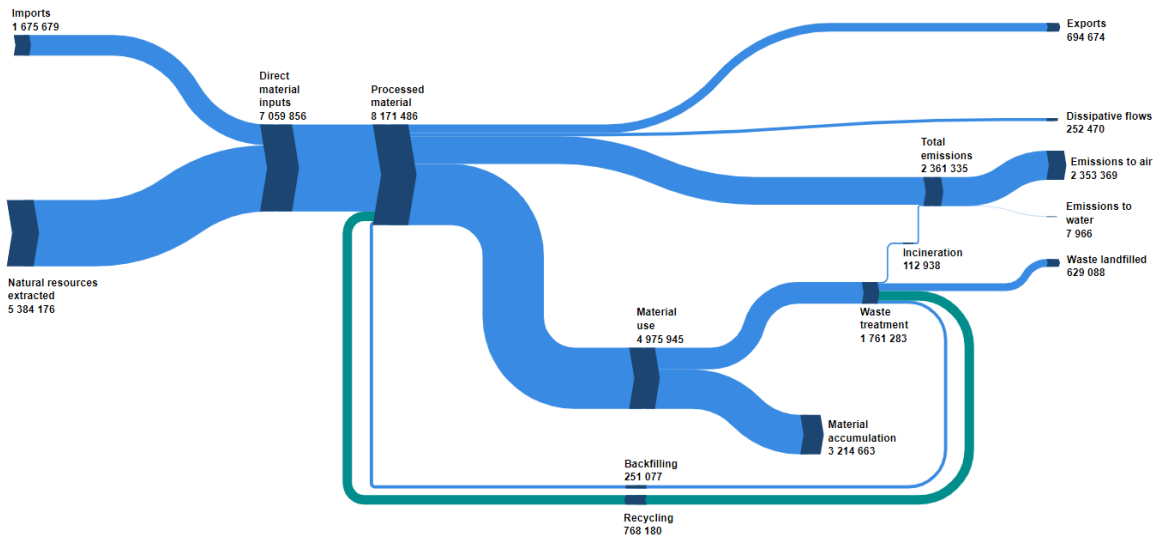

Figure 3. Material flow diagram in the EU, thousands tonnes (2022)

Source:https://ec.europa.eu/eurostat/cache/sankey/circular_economy/sankey.html?geos=EU27_2020&unit=THS_T&materials=TOTAL&material=TOTAL&highlight=0&nodeDisagg=0101100100&flowDisagg=false&language=EN

If for a company this can be calculated more simply (there is internal accounting, product sheets, etc.), the situation becomes much more complicated in the case of measuring circularity rates at the macro level (regional, national or international), this is because not always the flow of materials is accounted in the case of the

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transmission of recyclable materials between companies, which for a company can be accounted as a waste, and transmitted at a loss, but de facto used by another company.

There is currently no statistical information available on how the circularity rate is calculated for the Republic of Moldova or any of its companies.

II. THE EXTENT OF THE CURRENT STUDY OF THE PROBLEM, OBJECTIVE OF THE STUDY

Currently, several tools have been developed to assess circularity at various levels—micro (organization), or macro (national/regional). Despite the existence of these tools, they vary widely in methodology, scope, and applicability, making comparisons difficult. Moreover, gaps remain in terms of harmonization and standardization, with no global consensus on which indicators best reflect circular progress. The primary objective of this study is to review the available tools, highlight their challenges, and propose recommendations to improve circularity measurement.

The study will be focused on the tools used by companies, and also will include the existing methodologies used at macro level by Eurostat. In this article was used Eurostat's Circular Material Use (CMU) rate methodology.

By incorporating Eurostat's Circular Material Use (CMU) rate methodology into the analysis of the circularity in Republic of Moldova, this article aims to provide a comprehensive overview of the tool and to offer practical recommendations for improving the reliability, comparability, and effectiveness of these tools at both the organizational and macroeconomic levels.

III. METHODS AND MATERIALS APPLIED

The study employed a systematic review of literature and available tools that assess the circular economy. It analyzed qualitative and quantitative tools for their ownership, data requirements, indicators, and reporting capabilities. Tools reviewed include the Ellen MacArthur Foundation's Circulytics, the CTI Tool developed by the World Business Council for Sustainable Development, and various others focused on organizational circularity. At regional level was used the methodology from Eurostat - the calculation of Circular Material Use (CMU) rate.

IV. RESULTS OBTAINED AND DISCUSSIONS

According to UNECE/OECD (2023) guidelines for measuring circular economy" the Circular Economy (CE) concept is multi-dimensional. It relates to other concepts and principles, including but not limited to, resource productivity or resource efficiency, sustainable materials management and the so-called R-framework that now distinguishes 10 R strategies from the most circular to the least circular, including the 3Rs (reduce, reuse, recycle), and that can be applied to any stage of the production and consumption processes. It focuses on the circularity of the material flows and on the socio-economic and environmental benefits that arise from it, the goal being to lower natural resource extraction and decrease environmental and social impacts without an associated reduction of economic output. There is no common definition nor terminology for a CE. Its meaning varies across countries and literature.

The next are main working definitions of a circular economy, used usually to measure Circular Economy at regional or national level:

- *OECD working definition* - a circular economy is an economy that seeks to:
  - Maximise the value of the materials in the economy.
  - Minimise material consumption, in particular virgin materials, hazardous substances.
  - Prevent waste from being generated and reduce hazardous components in waste and products.
- *European Union and EEA - EU Action Plan for a Circular Economy***:** a circular economy, maintains the value of products, materials and resources in the economy for as long as possible, and the generation of waste minimized.
- *UNECE* **-** a circular economy aims to minimize globally the input of natural resources and the generation of residuals by maintaining the value of goods and materials for as long as possible and by returning materials into the product cycle at the end of their use" (UNECE/OECD, 2023).

With growing demand for circular economy related data, new frameworks are emerging. These include voluntary reporting frameworks, sector agnostic standards, goal-setting methodologies, sector guidance, and regulated sustainability disclosure frameworks.

The study revealed significant variability in how the circular economy is measured across different level. While material flow analysis (MFA) is widely used, it often fails to account for product durability, reuse potential, or the regenerative aspects of the CE. Similarly, many studies prioritize economic benefits (e.g., cost savings and resource efficiency) but overlook broader environmental and social benefits, such as ecosystem restoration and equitable resource distribution.

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Circular Economy assessment tools help organizations or countries to evaluate and improve their sustainability efforts by identifying areas where resources can be reused, recycled, or minimized. These tools vary in focus but generally assess aspects such as resource efficiency, waste reduction, product lifecycle, and environmental impact.

Here are some widely used tools applicable to organizations or countries:

- *Material Flow Analysis (MFA)* - tracks the flow of materials through an organization or system to identify inefficiencies and opportunities for resource reuse;
- *Life Cycle Assessment (LCA)* - analyzes the environmental impact of a product or service from cradle to grave (i.e., from raw material extraction to disposal);
- *Circularity Indicators* (i.e., Ellen MacArthur Foundation's Circulytics) - measures how circular an organization's products or processes are, considering aspects like product life extension, resource recovery, and waste reduction;
- *CE Value Mapping Tool* - visualizes value creation and destruction in linear vs. circular systems, helping organizations design business models that align with circular principles.

These tools enable organizations to systematically assess and improve their circular economy initiatives, aligning their operations with sustainability goals. The most useful tools for organizations are presented in the *Table 1*.

Table 1. Circular Economy assessment tools applicable to organisations

Design	Name	Description
CIRCULARITY ASSESSMENT	Circularity Assesment	A self-assessment tool to evaluate a business or a product through a circular lens. In the tool, it is possible to use various frameworks to help create a baseline overview of all the circular efforts by organisation. Using the outcomes of the assessment, it is possible to identify opportunities and challenges that can inform the organisation for circular pathway. M. A tool developed by Circle Economy (2024).
CIRCULYTICS	Circulytics	Circulytics, which was introduced in 2020, gave businesses a way to submit their data to the Foundation and get a personalized performance evaluation using a strict scoring system. More than 2,000 businesses joined, and their combined efforts significantly influenced the measurement environment for the circular economy and fueled the global adoption of circular business practices. A tool developed by Ellen MacArthur Foundation (2024).
CTI TOOL	**CTI Tool**	The CTI Tool was developed to help businesses in different industries worldwide to measure and improve their circular performance by supporting and guiding companies through the Circular Transition Indicators process. A tool developed by World Business Council for Sustainable Development and Circular-IQ (CTI Tool, 2024).
CIRCELLIGENCE BY BCG	**Circelligence**	Companies can become circular businesses and generate more value from fewer raw material inputs by implementing Circelligence by BCG. By incorporating circular economy principles into their overall business strategy and empowering management to make well-informed circular investment choices, Circelligence by BCG determines a company's circularity to assist clients on their climate change and sustainability journey. A tool developed by Boston Consulting Group (2024).

Source: Author own compilation

Key challenges identified include:

- *Lack of standardized metrics* - any CE measurement methods are context-specific, making it difficult to compare progress across industries or regions.
- *Data availability and quality* - collecting accurate, comprehensive data on resource use, waste streams, and lifecycle impacts is a significant hurdle for many businesses.
- *Inclusion of social factors* - current CE metrics largely focus on environmental and economic factors, neglecting social dimensions such as job quality and community impacts.
- *Technological gaps* - while digital technologies like IoT and blockchain show promise for tracking material flows, their implementation is still limited due to high costs and technical complexity.

Despite these challenges, the study also found positive examples of companies successfully integrating circular principles and measuring their impact. For example, companies in the electronics sector are increasingly using product lifecycle assessments (LCAs) to evaluate the environmental impacts of their products, from raw material extraction to disposal. In the food industry, initiatives like food waste recovery and resource-efficient packaging are contributing to measurable improvements in resource use efficiency.

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The tools identified in this study are categorized as qualitative, quantitative, or hybrid (a mix of both). However, none of these tools offer a complete picture, as each tool focuses on different aspects of circularity whether environmental, economic, or social. For instance, Circulytics includes both quantitative and qualitative metrics but lacks transparency regarding its calculation methods. Additionally, many tools fail to account for certain circular strategies such as resource recirculation and the environmental footprint at a granular level, leading to gaps in comprehensive assessment.

Another significant finding is the lack of standardization among circularity indicators. Tools use different scales, and even when they address similar concepts (e.g., waste reduction), they apply different methodologies, which results in non-comparable outputs. A major challenge also lies in the complexity of the data inputs required for some tools, as organizations often struggle to provide accurate and complete data.

For the Republic of Moldova, according the equation 1, we can estimate the CMU, by using the public data from the Environmental Agency (2011), National Bureau of Statistics of the Republic of Moldova (2021), UNECE and TradeMap public open database portal.

Table 2. CMU rate in the Republic of Moldova (for 2021)

Indicator	Quantity (tonnes)	Source of data
RCV_R	247.800	(Environmental Agency, 2021)
*IMP_W	49.500	(TradeMap, 2021)
EXP_W	127.500	(Environmental Agency, 2021)
**DMC	32.307.032	
Population	*2.626.588*	(National Bureau of Statistics, 2021)
DMC per capita	*12.3*	(UNECE, 2021)
CMU	**1%**	

Source: Developed by the authors

* Based on the Waste Law 209/2016 - it is forbidden to import waste and residues of any nature into the Republic of Moldova (art.63, 1), exception the wastes included in the Anex 7 (Parliament of the Republic of Moldova, 2016).

** For DMC – it was used the number of population from National Bureau of Statistics of RM, multiplied with the SDG 12/indicator 12.2.2. Domestic material consumption per capita, from UNECE. *(Population x 12.2.2)*.

Until now, the European Union has been the source of many of the circular measurement initiatives, but the publication of International Organization for Standardization (ISO) 59000 aids the global adoption of the circular economy. By creating a universal terminology, the concepts can be used not only by industry, but also by the public sector as a support for legislation and for regulatory purposes.

The standards thus create the framework for the future development of the circular economy. Moreover, the relevant standards can be used in public procurement, providing assurance that products compatible with the concept of circular economy are being purchased.

In June 2024, ISO has published a new family of EC standards. Standards are the first set of international definitions and rules for EC, and organizations from more than 100 countries have participated in their development. ISO 59000 divides the circular economy into 6 primary principles. The first principle is *systems thinking*, according to which the environmental, economic and social impact of operations must be considered. Other principles include creating value through resource-efficient solutions, sharing value, ensuring resource availability, traceability of resources along value chains, and protecting and restoring ecosystem sustainability and biodiversity. The standard outlines a wide range of activities that organisations can use to promote the circular economy. These include:

• rethinking products and services, product design and procurement, process optimization and industrial symbiosis;

• reuse, maintenance, repair and sharing,

• education for renovation, remanufacturing, recycling, recovery of materials and energy, research, innovation, behavior change, cooperation, policy, financing and digitalization.

The ISO 59000 family of standards (see Figure 4) is designed to harmonise the understanding of the circular economy and to support its implementation and measurement. It also considers stakeholders, such as governments, industry, and non-profit organizations, in contributing to the achievement of the United Nations (UN) 2030 Agenda for Sustainable Development.

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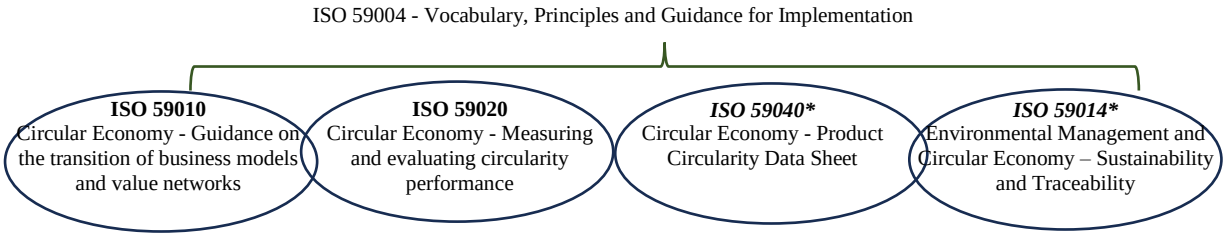
The ISO 59000 family of standards improves the understanding of the circular economy and supports its implementation and measurement. ISO 59004, ISO 59010, ISO 59020 and ISO/TR 59032 were published in May 2024 and ISO 59014, ISO/TR 59031 and ISO 59040 are being prepared (see *Figure 4*).



ISO/TR 59031* – Circular Economy – Performance-Based Approach – Case Study Analysis
ISO/TR 59032 – Circular Economy – revision of existing value networks

Figure 4. ISO 59000 standards family

Source: Author own compilation

According to ISO 59004, circular economy is: "an economic system that uses a systemic approach to maintain a circular flow of resources, by recovering, retaining or adding to their value, while contributing to sustainable development". ISO 59004, ISO 59010 and ISO 59020 are interlinked, as shown in Figure 4, and support organisations in implementing the transition to a circular economy.

The recently published standards represent a significant milestone, providing a common global understanding of the definition of the circular economy, business operations according to the business model and its monitoring and evaluation.

In order to ensure consistent and verifiable results, ISO 59020 attempts to standardize the procedure by which organizations gather and compute data using required and optional circularity indicators. It offers an organized framework for establishing system boundaries, choosing relevant indicators, and analyzing data in order to assess the performance of circularity at various levels, ranging from organizational and product-specific to regional and inter-organizational levels (ISO, 2024).

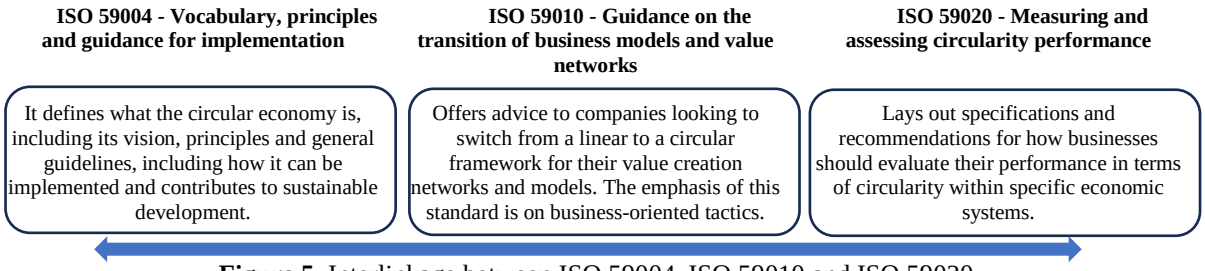


Figure 5. Interlinkage between ISO 59004, ISO 59010 and ISO 59020

Source: (International Organisation for Standardisation, 2024)

There is expectation that ISO 59020 will plays a key role in advancing the shift towards a circular economy by offering a comprehensive framework for evaluating circularity performance. This standard provides organizations with a structured approach to measure how well they are reducing resource consumption and promoting the efficient reuse of materials. By adopting ISO 59020, companies can better assess their environmental impact and improve their resource management strategies.

Beyond supporting environmental goals, ISO 59020 contributes to the broader objectives of sustainable development, aligning with the United Nations' 2030 Agenda and the Sustainable Development Goals (SDGs). For companies, the standard provides a reliable tool to track circular economy progress, demonstrating a strong commitment to sustainability. It enhances transparency and accountability, while also helping build trust among stakeholders by showcasing concrete efforts towards more sustainable and responsible practices.

We can see that the approval of the ISO 59000 family of standards in 2024 ultimately allows clarification on the definition of the circular economy, which in turn can facilitate the measurement of the circular economy, even though Kirchherr et al. (2023) note in their research "Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions" that the development of a "final" and consensus definition of CE is elusive. The primary goal of ISO 59020 is to offer a standardized methodology for measuring and assessing the circularity performance of products, services, and organizations. This can help businesses benchmark their performance, identify improvement opportunities, and communicate circularity efforts more effectively to stakeholders. It is applicable across industries and sectors, helping a wide range of organizations—from small businesses to multinational corporations—measure their circularity performance. It provides a consistent approach to calculating

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circularity indicators, enabling comparisons across companies and sectors. Similar to Life Cycle Assessment (LCA), ISO 59020 encourages a life cycle approach to assessing circularity, meaning that products and services should be evaluated from design, manufacturing, and use to end-of-life stages.

V. CONCLUSIONS

Measuring the circular economy presents significant challenges due to the absence of universally accepted metrics, difficulties in data collection, and sectoral differences in the implementation of CE practices. While progress has been made in certain areas, particularly with the use of material flow analysis and lifecycle assessments, these tools do not fully capture the holistic nature of the CE, particularly in terms of regeneration and long-term sustainability.

A clear and widely accepted definition of the circular economy (CE) is essential for effective policymaking. Such a definition establishes a shared foundation of objectives and assumptions, allowing policymakers to create more coordinated and cohesive strategies. This, in turn, enhances the ability to align policies across various levels — such as states, countries, and regions—as well as across industries like construction, textiles, and technology. Moreover, a unified understanding of CE can help bridge gaps across different stages of the product life cycle, from resource extraction to processing and end-of-life management.

For businesses, a consensus definition enables better alignment of circular economy practices with those of partners, suppliers, and broader industry standards, fostering more consistent and effective adoption of CE principles. Researchers also benefit from a common framework, as it allows for more collaborative and cross-disciplinary research efforts, facilitating a broader discourse across different sectors and academic fields.

Given the complexity and scope of the transition to a circular economy, it is critical to prevent differing interpretations of the concept from becoming obstacles to its implementation. A unified definition not only supports clearer communication but also aids in the ongoing refinement of CE strategies as the concept continues to evolve To improve the effectiveness of circular economy measurements, the following recommendations are proposed:

1.*Standardization of metrics* - there is an urgent need for globally accepted measurement frameworks that account for environmental, economic, and social dimensions of the CE.

2.*Investment in digital tools* - governments and industries should invest in technologies like IoT and blockchain to improve data tracking and transparency in resource use.

3.*Incorporation of social indicators* - measurement frameworks should include indicators that assess the social impacts of the circular economy, such as job quality and community well-being.

4.*Sector-specific guidelines* - measurement methods should be adapted to the specific needs and characteristics of different industries to ensure relevance and applicability.

In conclusion, advancing the measurement of the circular economy will not only provide clearer insights into the benefits and challenges of CE practices but also support more informed decision-making by policymakers and businesses. The circular economy represents a promising pathway toward sustainability, and robust measurement frameworks will be essential to realizing its full potential.

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