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Circular economy — Measuring and assessing circularity performance

Économie circulaire — Mesure et évaluation de la performance de circularité

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 323, *Circular economy*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

0.1 Background

The global economy is “linear” as it is mainly based on extraction, production, use and disposal. This linear economy leads to resource depletion, biodiversity loss, waste and harmful losses and releases, all of which collectively are causing serious damage to the capacity of the planet to continue to provide for the needs of future generations.[56] Moreover, several planetary boundaries have already been reached or exceeded.

There is an increased understanding that a transition towards an economy that is more circular, based on a circular use of resources, can contribute to meeting current and future human needs (welfare, housing, nutrition, healthcare, mobility, etc.). Transitioning towards a circular economy can also contribute to the creation and sharing of more value within society and interested parties, while natural resources are managed to be replenished and renewed and in a sustainable way, securing the quality and resilience of ecosystems.

Organizations recognize many potential reasons to engage in a circular economy (e.g. delivering more ambitious and sustainable solutions; improved relationships with interested parties; more effective and efficient ways to fulfil voluntary commitments or legal requirements; engaging in climate change mitigation or adaptation; managing resource scarcity risks, increasing resilience in the environmental, social and economic systems), while contributing to satisfying human needs.

The ISO 59000 family of standards (see Figure 1) is designed to harmonize the understanding of the circular economy and to support its implementation and measurement. It also considers organizations, such as government, industry and non-profit, in contributing to the achievement of the United Nations (UN) Agenda 2030 for Sustainable Development[54].

ISO 59004, *Circular economy — Vocabulary, principles and guidance for implementation*

ISO 59010 *Circular economy — Guidance on the transition of business models and value networks*	**ISO 59020** *Circular economy — Measuring and assessing circularity performance*	**ISO 59040** *Circular economy — Product circularity data sheet*	**ISO 59014** *Environmental management and circular economy — Sustainability and traceability of the recovery of secondary materials — Principles and requirements*

ISO/TR 59031, *Circular economy — Performance-based approach — Analysis of case studies*
ISO/TR 59032, *Circular economy — Review of existing value networks*

Figure 1 — ISO 59000 family of standards

0.2 Relationship between this ISO 59004, ISO 59010 and this document

ISO 59004, ISO 59010 and this document are interconnected, as shown in Figure 2, and support organizations in implementing a transition towards a circular economy.

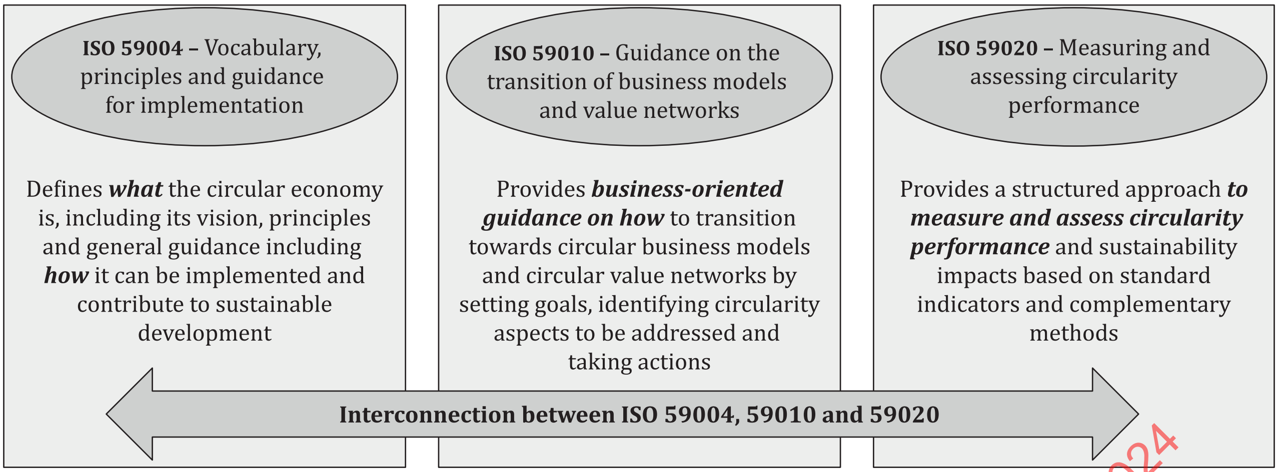


Figure 2 — Relationship between ISO 59004, ISO 59010 and this document

0.3 Purpose and the outline of this document

The purpose of this document is to assist organizations in the collection of the necessary information and the calculation to enable circular economy practices that minimize resource use and optimize the circular flow of resources, while contributing to sustainable development.

The results provide an integrated view of circularity and sustainable development and are intended to be used to support the transition towards a circular economy. In contributing to sustainable development this document also considers the UN Agenda 2030[54] and the Sustainable Development Goals (SDGs).

Terms, definitions and principles are provided to help users and other interested parties interpret and apply the guidance. This document provides a platform for the development of more detailed circularity assessment standards that are appropriate for individual sectors.

Circular economy — Measuring and assessing circularity performance

1 Scope

This document specifies requirements and gives guidance to organizations for measuring and assessing a defined economic system to determine their circularity performance at a specific time. Measurement and assessment are performed by the collection and calculation of data with the help of mandatory and optional circularity indicators.

This document provides a framework to guide users within organizations of all types and sizes through the measurement and assessment process, including system boundary setting and choice of indicators, as well as processing and interpreting data in a consistent and reproducible manner to generate meaningful and verifiable results.

The framework is applicable to multiple levels of an economic system, ranging from regional, interorganizational and organizational to the product level.

To measure and assess social, environmental and economic impacts that are caused by the actions of the organization to achieve circular goals and objectives, the document provides a list of complementary methods that can be used in addition to this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 59004, *Circular economy — Vocabulary, principles and guidance for implementation*

ISO 59010, *Circular economy — Guidance on the transition of business models and value networks*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 59004, ISO 59010 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms related to circularity and the circular economy

3.1.1
circular economy
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

Note 1 to entry: *Resources* (3.3.11) can be considered concerning both stocks and flows.

Note 2 to entry: The inflow of virgin resources is kept as low as possible, and the circular flow of resources is kept as closed as possible to minimize *waste* (3.3.12), *losses* (3.3.13) and *releases* (3.3.14) from the economic system.

[SOURCE: ISO 59004:2024, 3.1.1]

3.1.2
circular
aligned with the principles for a *circular economy* (3.1.1)

Note 1 to entry: Objectives and goals for a circular economy can be defined with respect to the principles for a circular economy.

[SOURCE: ISO 59004:2024, 3.1.14]

3.1.3
circularity
degree of alignment with the principles for a *circular economy* (3.1.1)

[SOURCE: ISO 59004:2024, 3.1.15]

3.1.4
circularity aspect
element of an organization's activities or solutions that interacts with the *circular economy* (3.1.1)

EXAMPLE Durability, recyclability, reusability, repairability, recoverability.

Note 1 to entry: Circularity aspects should be considered in relation to the principles, as well as the organization's objectives, goals and actions, for the implementation of a circular economy.

[SOURCE: ISO 59004:2024, 3.6.1]

3.2 Terms related to system, boundary and scope

3.2.1
system boundary
boundary representing physical, process, temporal and geographical limits of what is included and what is not included in an assessment

[SOURCE: ISO 21931-2:2019, 3.31]

3.2.2
system in focus
system that is defined by selected *system boundaries* (3.2.1) and is the subject of a *circularity measurement* (3.3.2) and a *circularity assessment* (3.3.3)

Note 1 to entry: Four system levels are being used for measuring and assessing *circularity performance* (3.3.1): regional, interorganizational, organizational and product level.

[SOURCE: ISO 59004:2024, 3.1.23]

3.3 Terms related to measurement and assessment

3.3.1
circularity performance
degree to which a set of *circularity aspects* (3.1.4) align with the objectives and principles for a *circular economy* (3.1.1)

[SOURCE: ISO 59004:2024, 3.6.3]

3.3.2
circularity measurement
process to help determine the *circularity performance* (3.3.1) through collection, calculation or compilation of data or information

[SOURCE: ISO 59004:2024, 3.6.4]

3.3.3
circularity assessment
evaluation and interpretation of results and impacts from a *circularity measurement* (3.3.2)

Note 1 to entry: Assessment includes consideration of the sustainability aspects and can apply *complementary methods* (3.3.7) such as life cycle assessment.

[SOURCE: ISO 59004:2024, 3.6.5]

3.3.4
circularity indicator
metric used to measure one or more *circularity aspects* (3.1.4)

Note 1 to entry: A circularity indicator can represent a measurable aspect or combination of aspects of a *resource* (3.3.11), a solution, process or action.

[SOURCE: ISO 59004:2024, 3.6.6]

3.3.5
quantitative indicator
measure based on numeric data that can be used for mathematical calculations and statistical analysis

Note 1 to entry: The input data can be directly measured or otherwise obtained.

Note 2 to entry: Quantitative input data are based on a physical or economic unit of measurement.

3.3.6
qualitative indicator
measure derived from a checklist or descriptive scale without any quantification

Note 1 to entry: Qualitative indicators can be categorized into classes that can be assigned numeric values.

3.3.7
complementary method
method, approach or standard that is used together with *circularity measurement* (3.3.2) to provide a *circularity assessment* (3.3.3)

3.3.8
primary data
data obtained from known direct measurement or from implicitly or explicitly defined calculations based on data originating from such direct measurement or calculations

[SOURCE: ISO 14033:2019, 3.1.5, modified — "or calculations" added.]

3.3.9
secondary data
data obtained in other ways than *primary data* (3.3.8)

EXAMPLE Literature, public or commercial databases, statistics, modelling or simulation.

[SOURCE: ISO 14033:2019, 3.1.6, modified — Example added.]

3.3.10
aggregation
process of combining data from various sources

[SOURCE: ISO/IEC 29182-2:2013, 2.4.2]

3.3.11
resource
asset from which a solution is created or implemented

Note 1 to entry: Depending on the context, reference to "resource" includes "raw material", "feedstock", "material" or "component".

Note 2 to entry: For the purpose of this document, asset refers to physical resources such as natural resources, virgin resources, recoverable resources and recovered resources.

Note 3 to entry: Resource includes any energy type (e.g. the energy content or energy potential of materials).

Note 4 to entry: Resources can be considered concerning both stocks and flows.

[SOURCE: ISO 59004:2024, 3.1.5]

3.3.12
waste
resource (3.3.11) that is no longer considered to be an asset as it, at the time, provides insufficient value to the holder

Note 1 to entry: The holder can choose to retain, discard or transfer the waste.

Note 2 to entry: Value can be assigned to waste as a result of a need from another interested party, at which point the resource is no longer considered waste.

Note 3 to entry: The assignment of value to waste as a resource is linked, in part, to the available technology (e.g. landfill mining).

Note 4 to entry: Some regulations require the holder to dispose of certain types of waste, while others assign value to waste.

Note 5 to entry: Because resources include the energy content or energy potential of materials, such energy, when liberated during a process and not recovered for another use, can be considered a waste.

[SOURCE: ISO 59004:2024, 3.3.6]

3.3.13
losses
unmanaged outflows of a *resource* (3.3.11) from the *system in focus* (3.2.2) that are not recovered

Note 1 to entry: For the purpose of measuring *circularity performance* (3.3.1), losses can be estimated.

Note 2 to entry: Losses can happen at any stage of the life cycle, such as wear and tear in the use stage (e.g. tire abrasion, microplastic).

[SOURCE: ISO 59004:2024, 3.3.7]

3.3.14
releases
managed emissions to air and discharges to water or land from the *system in focus* (3.2.2)

Note 1 to entry: Releases can be solid, liquid or gaseous.

Note 2 to entry: For the purpose of measuring *circularity performance* (3.3.1), releases are quantifiable but are not recovered at the time of emission or discharge.

Note 3 to entry: Releases can happen at any stage of the life cycle (e.g. car emissions).

[SOURCE: ISO 59004:2024, 3.3.8]

3.3.15
allocation
partitioning of the inflows and outflows of a process or a system between the *system in focus* (3.2.2) and one or more other systems

[SOURCE: ISO 14040:2006, 3.17, modified — "of" added after "partitioning" and the system in focus and one or more other systems" replaced "product system under study and one or more other product systems".]

3.3.16
data traceability
ability of data to be tracked to original and verifiable sources

Note 1 to entry: Including calculations and operations performed on the data.

Note 2 to entry: ISO 14033:2019 provides a framework both for how to achieve data traceability as well as how to audit and verify the level to which data traceability has been achieved.

Note 3 to entry: Data can be quantitative or qualitative.

3.3.17
reused content
component or part that has reached the end of one use, and is used again with minimal or no physical alterations

Note 1 to entry: Minimal alterations include cleaning or minor adjustments or repairs.

Note 2 to entry: Non-minimal alteration of materials and parts can contribute to *recycled content* (3.3.18). In this document, recycled content and reused content are treated as distinct and separate shares of total content.

3.3.18
recycled content
proportion, by mass, of *recycled material* (3.3.19) in a product

[SOURCE: ISO 14009:2020, 3.2.23]

3.3.19
recycled material
material that has been reprocessed from recovered or reclaimed material by means of a manufacturing process

[SOURCE: ISO 14009:2020, 3.2.10, modified — "and made into a final product or into a component for incorporation into a product" and notes to entry deleted.]

3.3.20
durability
ability of a product or material to function as required, under specified conditions of use, maintenance, repair and update until a limiting state prevents its functioning

Note 1 to entry: Durability can be expressed in units appropriate to the part or product concerned (e.g. operating cycles, distance run). The units should always be clearly stated.

Note 2 to entry: Durability is influenced by reliability, maintenance, repair and updates (e.g. in software).

3.3.21
renewable energy
energy from a renewable resource

[SOURCE: ISO 59004:2024, 3.3.9]

4 Principles of measuring and assessing circularity

4.1 Circular economy principles

A system that is the subject of the circularity measurement and assessment is referred to as the "system in focus". In measuring and assessing the circularity performance of a system in focus, the circular economy principles of ISO 59004 should be considered. These are:

— systems thinking;

— value creation;

— value sharing;

— resource stewardship;

— resource traceability;

— ecosystem resilience.

4.2 Circularity measurement and assessment principles

4.2.1 General

In addition to the general circular economy principles, the following specific measurement and assessment principles should be applied:

— ensure relevant boundaries (see 4.2.2);

— ensure meaningful outcomes (see 4.2.3);.

These principles are also applicable to measuring and assessing the sustainability impacts within the system in focus, and towards wider social, environmental and economic systems.

4.2.2 Ensure relevant boundaries

4.2.2.1 General

The boundaries of the measurement and assessment should be based on a life cycle perspective and appropriate spatial (see 4.2.2.2) and temporal boundaries (see 4.2.2.2) should be chosen.

4.2.2.2 Spatial scale

The spatial scales reflect clear boundaries of the system in focus and its interconnection with the wider socio-economic and environmental other systems.

On the product level, the spatial scale covers different stages across the value chain or value network (e.g. from extraction, processing and supply of materials, manufacturing of parts and products, distribution, use, maintenance and repair to end of life). Such stages are typically located in different places, reflecting the cross-territorial nature of value chains and value networks.

4.2.2.3 Temporal scale

The time scale chosen encompasses the entire life cycle of the system from creation through to final end of life and disposal.

For extended temporal scales, consideration should be given to making periodic measurements and assessments at appropriate intervals to account for changes in inflow or outflow characteristics, properties or values to be accounted for (e.g. new recycling or reuse technologies, changed legislation for end of life treatment, new insights in regeneration of ecosystems).

4.2.3 Ensure meaningful outcome

The methods, models, procedures and data sources used in a circularity assessment should be transparent and understandable for the interested parties involved which include, for example, the target audience, suppliers, users and consumers. Data used in a circularity measurement and assessment should be traceable and as complete as possible. All resource inflows and outflows of the system in focus shall be quantified, when applicable. Any data assumptions or estimates should be properly described. Where possible, the circularity measurement and assessment should allow comparability to other similar or related systems whether internal or external to the system in focus.

5 Framework for measuring and assessing circularity performance

5.1 Framework introduction

The framework for measuring and assessing circularity performance consists of several interrelated stages which can be repeated as required. The framework is illustrated in Figure 3.

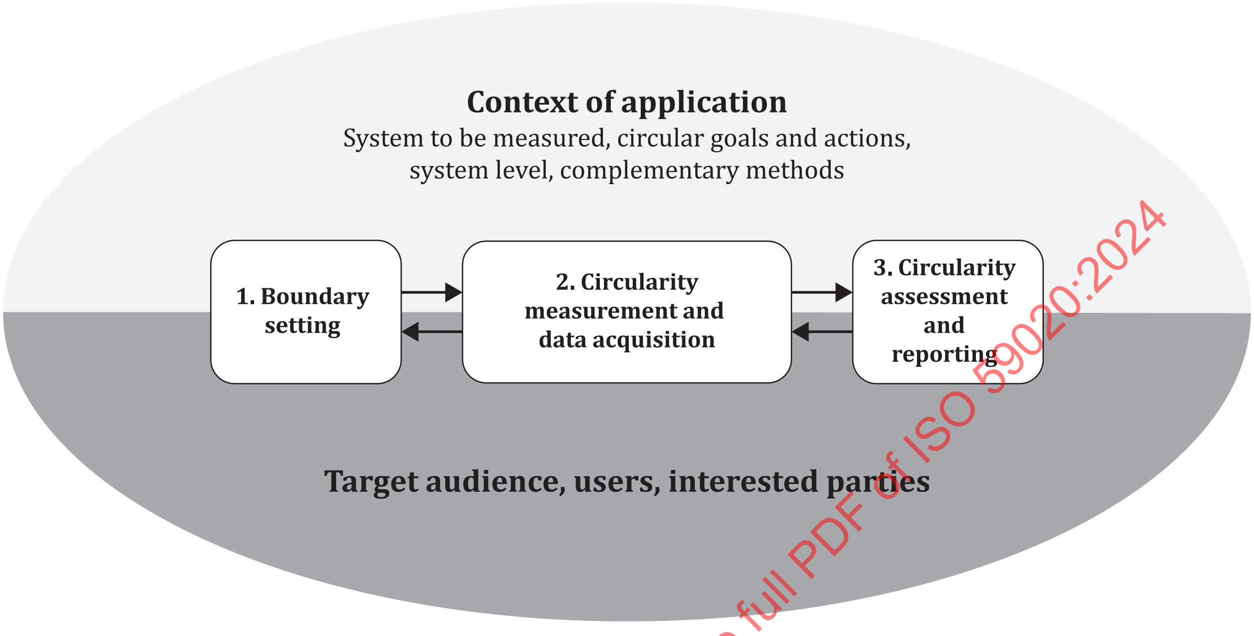


Figure 3 — Framework for measuring and assessing circularity

An overview of the individual stages within a measurement and assessment of circularity is summarized in this clause, while more detailed guidance is described in later clauses.

The framework can receive input from a management system and provide results back to the management system. The outcome of the measurement and assessment process is specific to a defined moment in time or time period for which the measurement and assessment are conducted. To monitor progress over time, the organization should carry out periodic assessments. To enable interpretation, transparency and verification of results, it is necessary that all stages are properly documented.

5.2 Context of the application

The circular goals and actions of the organization which are defined in ISO 59004, ISO 59010 or ISO 59014[1)] are important elements of the context of the application. The context of the application for measuring and assessing circularity provides the input for Stage 1 boundary setting (see 5.3) regarding the following questions:

— Which system level (e.g. regional, interorganizational, organizational or product) is applicable for the system in focus?

— Which circular goals (e.g. increasing reused content by X %, increasing recycled material derived from outflow to Y %) are applicable to the measurement?

— What circularity aspects (e.g. repairability, reusability, recoverability, durability) are of specific interest?

— Which specific social, environmental and economic issues, or SDG targets should be considered for possible impacts?

NOTE See Annex D for examples of relationships between SDG targets and circularity indicators.

1) Under preparation. Stage at the time of publication: ISO/FDIS 59014:2024.

— What is the purpose of the application (e.g. establishing a baseline, providing input for internal monitoring, internal comparative assertions, information for interested parties such as value chain actors, internal communication to users, experts involved)?

5.3 Stage 1: Boundary setting

Setting the boundaries for the system to be measured and assessed is determined by the context of the application as described in 5.2.

The boundary setting stage includes activities such as:

— defining the system in focus and its interactions with economic, social and environmental systems;

— defining which value network actors or interested parties are part of the system in focus and how to share information;

— defining data quality requirements.

For detailed guidance, see Clause 6.

5.4 Stage 2: Circularity measurement and data acquisition

The circularity measurement stage includes data acquisition. During circularity measurement, the circularity indicators are specified in relation to the data and information to be acquired, measured and calculated. The indicators described in this document are generally applicable for all system levels and all sectors, and can serve as a basis to form more detailed sector-specific measurement methods when required.

To achieve a balanced measurement, the measurement shall include the mandatory core circularity indicators when measuring the resource inflows and outflows (see 7.3, Table 3, and Clauses A.2 and A.3).

When applicable, the core circularity indicators on energy, water and economics from Clauses A.4, A.5 and A.6 should be measured.

The process of measuring circularity and data acquisition consists of different steps with the possibility of iteration, as shown in Figure 4.

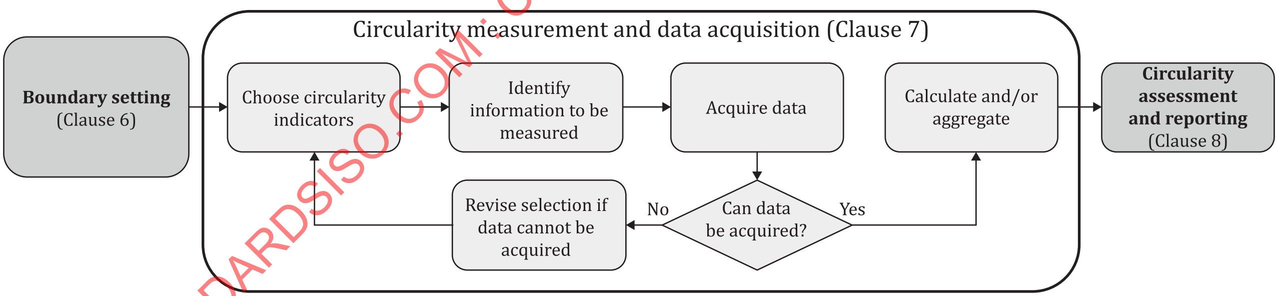


Figure 4 — Circularity measurement and data acquisition process steps

Circularity is measured using indicators to address relevant circularity aspects (e.g. recyclability) of the system in focus. A materiality approach (i.e. the identification of issues of the most importance to an organization's business) can be valuable to prioritize and select relevant indicators for the measurement (see the indicators in Annexes A and B).

During the data acquisition, representative and verifiable data for the selected circularity indicators are acquired. The circularity indicators are calculated using primary or secondary data. In cases where those data are not available, insufficient or otherwise do not meet specified quality requirements, alternative sources of data or different indicators should be used.

For detailed guidance, see Clause 7 and Annexes A and B.

5.5 Stage 3: Circularity assessment and reporting

The circularity assessment and reporting stage is the evaluation of the results of the circularity measurement. The circularity assessment should result in a comprehensive statement about the circularity performance of the system in focus.

The measurement and assessment of impacts on social, environmental and economic aspects is part of this assessment stage. The organization can apply complementary methods to measure and assess such sustainability impacts. This document does not include or duplicate those methods but encourages organizations to contribute to sustainable development and avoid unintended negative impacts when performing circular actions.

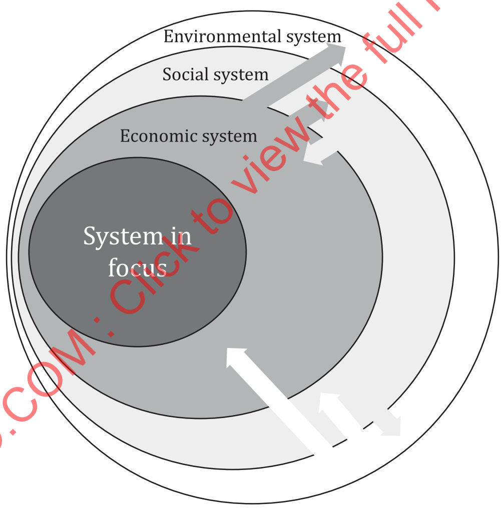
For detailed guidance, see Clause 8.

Examples of complementary methods are described in Annex C.

6 Boundary setting

6.1 System to be measured

The system in focus is a part of a wider economic system, connected to the social and environmental systems. The relationships between the different systems are shown in Figure 5, which schematically illustrates the boundaries between systems with arrows illustrating interactions and resource movement between each system.



NOTE Adapted from ISO 59004:2024, Figure 3.

Figure 5 — System to be measured and its relationships with the other systems

6.2 Determining the circularity measurement and assessment goal and scope

In general, the purpose of circularity measurement and assessment is to gain insight into the circularity performance of a specific system at a specific time. In measuring and assessing the circularity performance of a system, a life cycle perspective should be applied. This perspective should include all stages of technical or biological cycles over appropriate timescales that are related to that system. This can include connections throughout its value chain.

The context of the application, as described in 5.2, provides input to define the goal and scope of the circularity measurement and assessment by:

— defining circular goals to be measured;

EXAMPLE 1 Increase the average lifetime of a product or component relative to the industry average by X %, reduce the non-renewable content of the resources used by an organization to X %, increase the per cent actual recycled material derived from outflow of the organization to X %, increase the recycling of plastic in a city to X %, increase the amount of reused components in a product by X %.

— defining the system in focus, i.e. at which system level, what functional units, what locations, what parts of a value chain or value network, which regions, etc., are to be measured and assessed;

— defining data quality requirements;

EXAMPLE 2 X % of all measured data for resource inflows and resource outflows (by mass) must be primary.

— pre-selecting complementary methods for social, environmental and economic impact measurement and assessment;

EXAMPLE 3 ISO 14044 for life cycle assessment (LCA), ISO 26000 for social responsibility.

— defining the interested parties involved (e.g. the users or practitioners carrying out or using the measurement and assessment), the target audience (e.g. to whom the results of the assessment will be communicated, internal and/or external), other interested parties (e.g. related to acquiring the data and assessing the impacts) and organizations outside the system in focus that can be impacted (e.g. companies within the value chain);

— defining whether the results are to be used for internal monitoring or external communication;

— defining the boundaries of the system in focus with the wider economic system (e.g. value chain or network) and social and environmental systems.

Due to the iterative nature of the circularity measurement and assessment process, the goal and scope can be revised and updated due to unforeseen limitations (e.g. time needed), constraints (e.g. data shortages) or because of new or additional information. Such modifications, together with their justification, should be appropriately documented or communicated to the relevant interested parties.

6.3 Defining all resource inflows and outflows of the system in focus

Circular flows can be internal to the system in focus (e.g. an organization recovers products for remanufacturing which were leased to the customer) or external to the system in focus (e.g. the purchase of recycled materials from third parties). Figure 6 illustrates circular and non-circular flows internal or external to the system in focus.

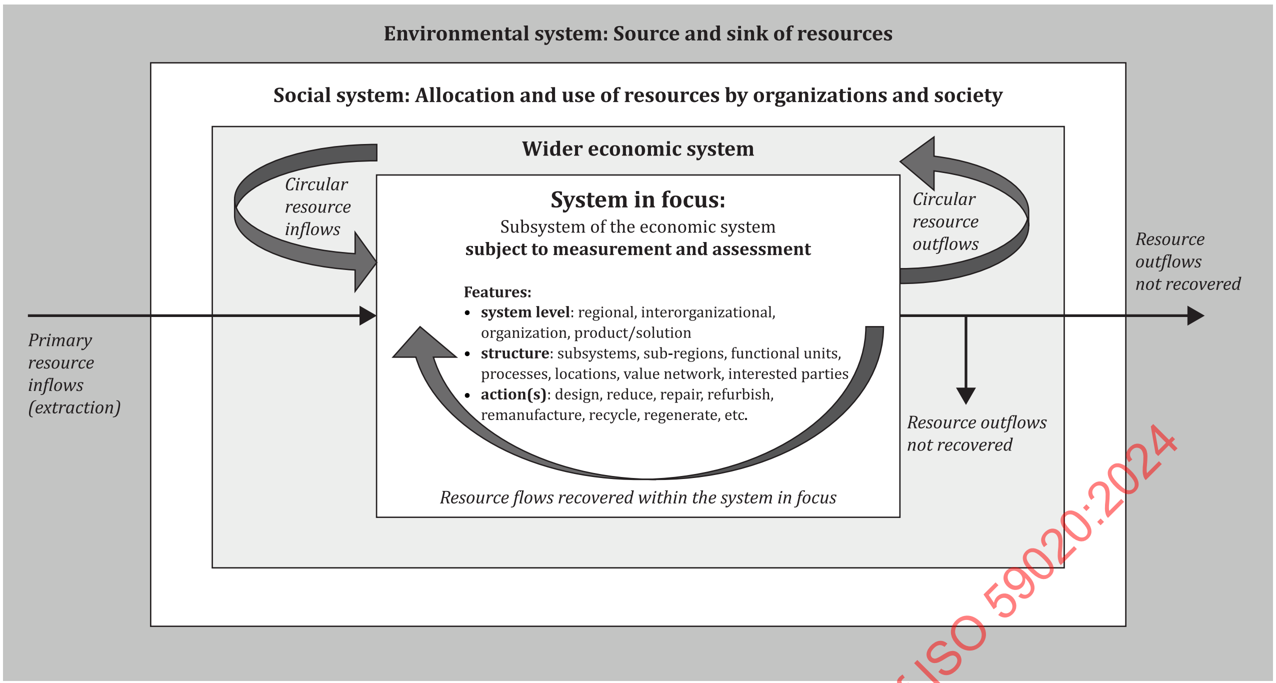


Figure 6 — System in focus and its boundaries

The following explanations are applicable to Figure 6:

— Virgin resource inflows can be renewable or non-renewable.

— Resource outflows not recovered by the system in focus can be recoverable or non-recoverable but are considered non-circular when leaving the system in focus. It is possible that the resources can be recovered in the wider economic system (e.g. in other systems with other technologies). These resources can be:

  — products or resources not recovered;

  — waste (e.g. when considered by the system in focus to have insufficient value);

  — releases (e.g. emissions to air, discharges to water and land);

  — losses.

— Circular resources in the wider economic system can flow to and from the system in focus.

— Resources recovered within the system in focus and used again are circular.

The boundaries and relationships between the environmental system, the social system and the economic system should be specified:

a) The environmental system represents the biosphere and the source and sink of resources. Applying a life cycle perspective, the organization should measure the acquisition of resources from the environmental system needed for the operation of the system in focus, such as forestry and mineral resources, as well as releases from the system in focus to the environment, such as emissions to air and discharges to water and land. The environment can also be impacted by losses as uncontrolled outflow of resources that are not recovered within the system in focus. Examples include microplastics from wear and tear, rotting of food during storage or transportation, or mismanaged urban littering.

b) The social system represents health, quality of life of humans and the prosperity of their societies. The organization should consider the interaction of the system in focus with the social system. The health and quality of life of consumers and citizens can be impacted by circular outflows and non-circular outflows.

EXAMPLE 1 Ending the dumping of used clothes in landfills near local communities can positively influence the quality of life of those communities.

EXAMPLE 2 The health and safety of workers can be impacted by creating products that can safely be dismantled and release no hazardous substances when being recycled.

c) The economic system supplies the system in focus, for example, with virgin resources acquired from the environmental system. The economic system can also supply the system in focus with renewable or non-renewable resources coming from other systems. The economic system receives circular and non-circular resources from the system in focus. It is also possible that resources not recovered by the system in focus can be recovered and turned into useful resources again by the wider economic system. Socio-economic aspects can be influenced by the actions of the system in focus, such as new jobs for repair, refurbishing, reverse logistics, recycling or circular design.

To measure the circularity performance of a system that is influenced by actions (such as circular design, reduce, refurbish, remanufacture, recycle, industrial or regional symbiosis), it is necessary to describe the system in focus with sufficient detail to trace changes in resource flows and related increases and decreases in stocks.

A material flow analysis (MFA) or resource flow analysis (RFA) approach can be helpful in quantifying resource or material flows of a system in focus between processes, and stocks of resources or materials within processes in a balanced way. The boundaries should be set to allow a resource balance to be achieved such that resource inflow is equal to resource outflow. The 100 % formulae on resource inflow and resource outflow should be applied, as explained in Annex A. This demands consideration of what data are needed, how data can be sourced, the nature and origin of the data, and a clear selection of temporal and spatial scales.

The system boundary can encompass multiple life cycles.

6.4 Temporal boundary setting

6.4.1 General

The system in focus and its inflows and outflows are measured at a specific moment in time. The data to be acquired for the inflows and outflows of the system in focus should represent a life cycle perspective.

6.4.2 Temporal boundaries

The temporal boundaries should be chosen to account for resources from their extraction through to their final end of life, i.e. through all use cycles. This approach avoids so-called “greenwashing”. However, very long temporal boundaries can be a challenge because information from several organizations in an entire value chain can be needed.

EXAMPLE 1 For a company that manufactures plastic from fossil fuels and sells plastic to other users, temporal boundaries are chosen that require all manufacturers, users, recyclers and end-of-life management companies to provide information.

EXAMPLE 2 Computer chip manufacturers map “buy-in” processed silicon wafers for processing, but the organization considers the extraction and processing of silicon dioxide raw materials through to wafers.

There can also be challenges if the life of solutions is very long such as in construction. Because of these challenges and the constraints and uncertainty of data, the organization can choose to shorten the temporal boundaries. Shorter timescales that do not consider an entire life cycle should be documented in the assessment report. The temporal boundaries are also relevant when assessing the sustainability impacts.

6.4.3 Measurement periods

The organization carrying out a circularity measurement and assessment should consider the time period over which data are measured or collected. To carry out an accurate resource flow means that the organization should choose an appropriate timescale for each relevant inflow and outflow of the system in focus. Resource flows can have seasonal and other fluctuations and some resources (e.g. petroleum products) can be sourced when prices are low. If possible, data should be collected over the same period or normalized where this is not possible.

6.4.4 Periodic monitoring

The organization can decide to do a periodic measurement of the circularity performance of the system in focus and to assess its impacts to monitor progress.

EXAMPLE The organization measures the effects of introducing a renewable material into a process stream every six months.

For this, the system in focus and its inflows and outflows are measured at specific moments in time, but can represent a particular time period, representing a time-resolved series of “snapshots”.

6.5 System perspective at different levels

6.5.1 Regional level

The regional level includes geographical areas such as countries, regions (e.g. within and between countries), cities, and districts within cities and local communities. It can also be continental or global and can extend to planetary dimensions including the atmosphere and the Earth’s orbit. Measuring and assessing at the regional level can require interacting with various organizations (e.g. agencies) within a city, district, county or local municipalities.

EXAMPLE The circularity performance of an aggregated system level, such as a country, is based on statistics and data from representative cities, counties and states.

NOTE A region can combine several sub-regions, nations or states with distinct jurisdictions and regulations that affect an organization’s circularity aspects, such as different incentives for take-back schemes or for handling not recovered resources. Similarly, an organization’s actions merit attention at an appropriate geospatial scale to address issues that vary within and across regions, such as air quality or water scarcity.

6.5.2 Interorganizational level

This level describes how groups of organizations cooperatively use resources to implement circularity aspects of solutions, products or projects. These groups can be within one specific sector, a specific value network or can be intersectoral in nature.

EXAMPLE At an industrial park, a community of different manufacturing and service companies collaborate in the management of resource flows to enhance the circularity performance of the group of organizations (e.g. in applying industrial symbiosis).

NOTE Interorganizational systems can encompass several different regions or nations with individually different circularity-related jurisdictions and resource resilience.

6.5.3 Organizational level

An individual organization can own and govern multiple organizations or subsidiaries. In practice, it can form its own value network, with multiple interorganizational levels (see 6.5.2). One or more subsidiaries can co-execute a circular project such as a large infrastructure development and building works. The system in focus can encompass multiple functional units and locations.

6.5.4 Product level

Measuring and assessing at the product level usually implies interaction with the organizational level (see 6.5.3) and interorganizational level (see 6.5.2), including interested parties within the value chain or network.

EXAMPLE 1 If the system in focus is “mobile phone X”, this can require a boundary setting at the interorganizational level (e.g. the mobile phone manufacturer who wants to refurbish the phone, together with component suppliers and distributors and collectors).

The user that is performing the circularity measurement should obtain data, either directly or indirectly, from the value network.

EXAMPLE 2 If an organization is manufacturing a product from raw materials, even if as a purchaser, setting boundary conditions that include raw material extraction can be needed.

If the organization is assembling a product from pre-prepared components, due to their complexity, the circularity of the individual components can be more relevant. Unless the circularity data for the components are from a verifiable and trusted source (e.g. they arise from third parties outside the system in focus), the components should be assumed to be linear in nature.

If a product is returned to the manufacturer for remanufacture or parts reuse, then the end-of-life resource flows and percentage of reused parts can be reliably measured since the circular flows are internal to the system in focus.

When data exchange of product circularity data through the value chain is required, International Standards such as ISO 59040[2)] and IEC 82474-1[3)] should be applied.

In ISO 59004, a product level is not defined or used but instead is considered as part of an organizational level or interorganizational level.

NOTE A solution is also applicable to this level.

7 Circularity measurement and data acquisition

7.1 Circularity measurement taxonomy

This document provides a taxonomy of circularity indicator categories and indicators to measure and assess the circularity performance of a system in focus. The taxonomy is founded on the objectives listed in the ISO 59004:2024, 3.1.1, definition of a circular economy to maintain a circular flow of resources, i.e. retain, recover and add value to those resources. The taxonomy provides a structure to measure the flow of resources and the degree to which circular goals and actions of the organization contribute to the circularity performance of the system in focus at a specific moment in time.

Figure 7 illustrates the taxonomy (in the centre), its connections to the circular goals and actions of the organization (on the left), and measuring and assessing the sustainability impacts of those actions (on the right).

2) Under preparation. Stage at the time of publication: ISO/DIS 59040:2023.

3) Under preparation. Stage at the time of publication: IEC/DIS 82474-1:2023.

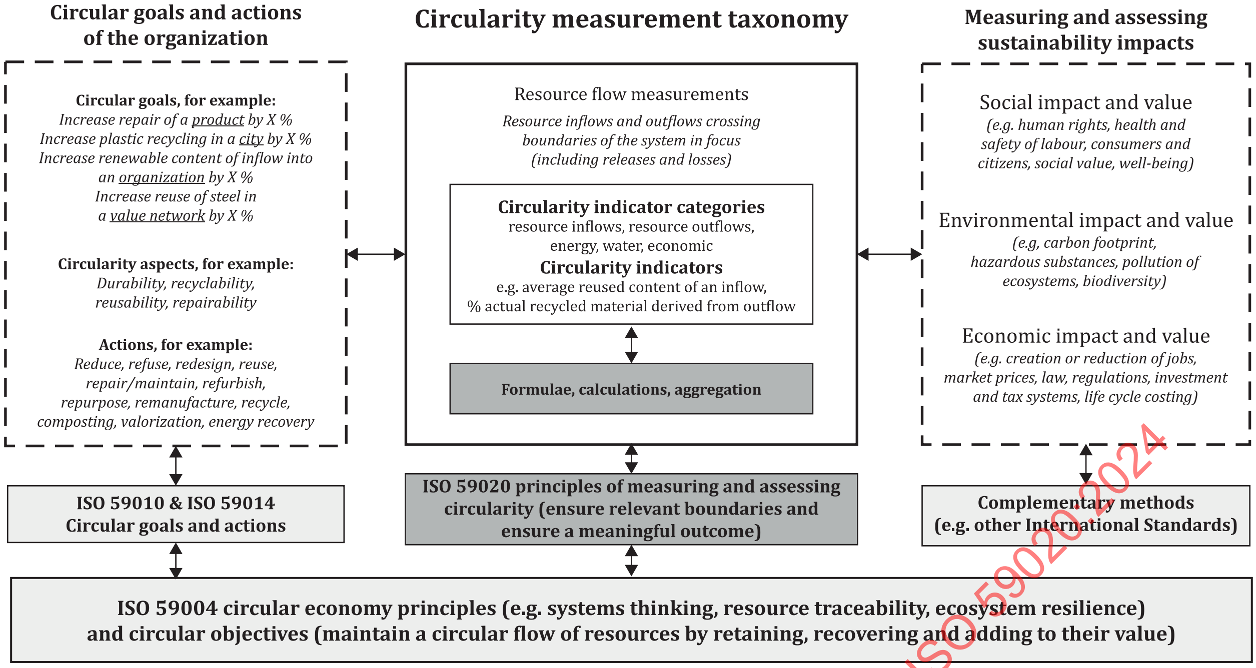


Figure 7 — Circularity measurement taxonomy and interactions

The three boxes in Figure 7 are further explained as follows, starting with the taxonomy itself:

a) The taxonomy on circularity indicator categories and indicators (centre box): This provides structure to the choice and use of circularity indicators. In measuring the circularity performance of a system in focus, the inflows and outflows of resources are measured with the help of selected circularity indicators. How to choose the indicators is described in 7.3. More detailed guidance, conditions, formulae and examples are included in Annexes A and B. Resource flows can influence stocks. Guidance on calculations and data aggregation is provided in Annexes A, B and G.

b) Actions of the organization, e.g. circular goals, actions and circularity aspects (left box): This provides input for the circularity measurement and assessment, based on circularity aspects of the organization's circular goals and actions, that are related to the system in focus. ISO 59010 and ISO 59014 define circular goals, actions and aspects that require relevant indicators to be selected from the taxonomy.

c) Measuring and assessing sustainability impacts (right box): This represents the measurement and assessment of sustainability impacts that result from the circular goals and actions of the organization. The positive or adverse effects on social, environmental and economic issues should be measured and assessed in the system in focus and the wider economic, social and environmental systems. Complementary methods including existing International Standards can help to measure and assess those impacts (see Clause 8). This document does not include or duplicate those methods but suggests that organizations apply selected complementary methods (see Annex C for examples).

The circular economy objectives and principles of ISO 59004, together with the principles of measuring and assessing circularity in Clause 4, are the fundamental basis for application of the circularity measurement taxonomy, as indicated in the bottom bars of Figure 7.

Tables 1 and 2 provide examples of a circularity measurement at an organizational level, whereby different objectives, actions, indicator categories and indicators are listed.

Table 1 — Example 1 of circularity measurement at an organizational level

Circular economy measurement	Indicator category		
	Resource inflow	Energy	Water
Objective: Value recovery	Average recycled content of an inflow (*X*) (see A.2.3)	Average per cent of energy consumed that is renewable energy (see A.4.2)	Ratio (on-site or internal) water reuse or recirculation (see A.5.4)
Actions	Circular procurement	Use of renewable energy	Reuse

Table 2 — Example 2 of circularity measurement at an organizational level

Circular economy measurement	Indicator category		
	Resource inflow	Economic	Resource outflow
Objective: Retaining resource value	Average reused content of an inflow (*X*) (see A.2.2)	Resource intensity index (see A.6.3)	Per cent actual reused products and components derived from outflow (*X*) (see A.3.3)
Actions	Reuse	Reduce	Design for circularity

7.2 Introduction to circularity indicators

A circularity indicator represents a quantitative or qualitative measure of a circularity aspect. Indicators can be used at any life cycle phase of a solution. This includes, for example, during simulation to test circular designs or during production, use, remanufacturing, repurposing and recovering.

An indicator is defined by the following:

— Circularity aspect: an element of an organization’s activities or solutions that interacts with the circular economy.

— System level: level varying from regional, interorganizational and organizational to product level.

— Measurement unit: for quantitative indicators, the unit of the indicator, such as an amount of mass in relation to a system reference unit, such as “tonne per 50 years” or “kg per product life cycle”. For qualitative indicators, a clear description of the quality it represents is needed.

— Data requirements: requirements for the data needed to measure and calculate attributes of the system in focus should be specified, such as “acquire primary data for resource inflow” or “use secondary data” of a specific publicly available database to represent recycled content of resources.

— Calculation or aggregation that is needed to convert the acquired data into a form or numeric value, such as “add all acquired data into a total sum”, “calculate the average of all acquired data” or “provide a panel of experts to interpret the acquired data into a qualitative statement”.

Well-defined and consistent assessment methods for circularity indicators are needed to ensure consistent calculation and interpretation of the results. Existing standards, norms or regulations providing a clear definition and procedure on how to measure data and calculate or evaluate the circularity indicator are used.

7.3 Choice of indicators for circularity measurement

7.3.1 Core circularity indicators

A minimum set of quantitative core circularity indicators that should be considered for circularity measurement and assessment is provided in Annex A.

Table 3 lists the name and a brief description of each core circularity indicator along with a reference to the subclause in Annex A that provides additional specifications or recommendations for measurement and calculation formulae. These core circularity indicators are in active use as part of circularity indicator systems and are recognized as providing an effective and practical measure of circularity performance.

The resource inflows and resource outflows of the system in focus shall be quantified and fully balanced with the use of the mandatory indicators in Clauses A.2 and A.3, taking changes in stocks into account. If a core circularity indicator is not applicable, the organization should explain why and can count the indicator value as zero.

The circularity indicators are organized into categories such that material, water and energy are treated separately. This separation is because water and energy both have unique aspects that should be measured to determine the circularity performance. The reference to "material" includes all physical resources except those that are explicitly addressed in other circularity indicator categories. "Material" includes manufactured products given that they are composed of materials.

The core circularity indicators can be supplemented by additional circularity indicators to meet the goal and scope of the circularity measurement and assessment. A materiality approach can be valuable to prioritize and select relevant indicators for the measurement. Annex B provides examples of additional indicators.

Table 3 — Core circularity indicators

Indicator category	Mandatory/ optional	Circularity indicator	Summary description (see Annex A for technical specifications)	Additional information
Resource Inflows	Mandatory	A.2.2 Average reused content of an inflow (X)	Fraction of input material resources that are reused components and products	Retaining resource value
	Mandatory	A.2.3 Average recycled content of an inflow (X)	Fraction of input material resources that is recycled material	Add resource value
	Mandatory	A.2.4 Average renewable content of an inflow (X)	Fraction of material resources inflow (X) that is sustainably produced renewable material	Add resource value
Resource outflows	Optional	A.3.2 Average lifetime of product or material relative to industry average	Indicator of time that an output resource (e.g. product) will remain in use compared to an industry average for the resource	Retaining resource value
	Mandatory	A.3.3 Per cent actual reused products and components derived from outflow (X)	Fraction of outflow that is reused	Retaining resource value
	Mandatory	A.3.4 Per cent actual recycled material derived from outflow (X)	Fraction of outflow that becomes recycled material	Recovering resource value
	Mandatory	A.3.5 Per cent actual recirculation of outflow in the biological cycle	Fraction of outflow content that is recirculated at end of life for safe return to the biosphere and meets the qualifying conditions for recirculation	Recovers resource value
Energy	Optional	A.4.2 Average per cent of energy consumed that is renewable energy	Fraction of net consumed energy that qualifies as renewable energy, taking into account both energy inflows and energy outflows	Recovering resource value

Table 3 *(continued)*

Indicator category	Mandatory/ optional	Circularity indicator	Summary description (see Annex A for technical specifications)	Additional information
Water	Optional	A.5.2 Per cent water withdrawal from inflow circular sources	Per cent of annual water demand that is derived from circular sources	Maintains a circular flow of resources
	Optional	A.5.3 Per cent water discharged in accordance with quality requirements	Per cent (by volume) of total water withdrawn that is discharged in accordance with circularity principles	Maintains a circular flow of resources
	Optional	A.5.4 Ratio (on-site or internal) water reuse or recirculation	Reuse cycles of on-site water	Maintains a circular flow of resources
Economic	Optional	A.6.2 Material productivity	Ratio of revenue generated by total mass of all linear resource inflows	Indicates resource reduction
	Optional	A.6.3 Resource intensity index	Quantitative measure of economic growth versus total resource use	Indicates resource reduction

EXAMPLE Durability of a car.

The durability of a car can be defined as the number of kilometres after which the car body must be dismantled. Some repair and maintenance operations can occur during the use stage. As the product is offered on the market, details about the limiting events must be specified by the supplier.

The terms “primary content”, “reused content”, “recycled content” and “renewable content” must be defined in a way that for any product the sum is 100 %. If the recycled content is 50 % and the reused content is 20 %, then the primary content is 30 %.

The reused content of a car consists in the total mass of spare parts from other cars which have been dismantled after use and implemented into the car under study.

The recycled content is the total mass of recycled material (e.g. recycled metals and recycled plastics) within a car. It is clarified to which extent process scrap can be defined as recycled material.

The primary content is the total mass of the car minus the reused content and the recycled content.

7.3.2 Additional indicators to support flow measurements

The core circularity indicators can be supplemented by the additional indicators or recommendations addressed in Annex B. However, other indicators can still be needed such as the following:

a) Identifying and creating flow measurement indicators to reflect the changes of shifting from product sales, for example:

   1) a list of resources needed to convert a product into a product-service-system;

   2) a list of resources needed to maintain the product service function.

b) Identifying and creating flow measurement indicators to reflect reductions in material purchased and handled (e.g. due to cooperative material minimization), for example:

   1) a list of materials regularly procured and handled; to cooperative supply-chain material minimization;

   2) a list of resources needed for the collective production and handling of materials.

7.3.3 Indicators to enable sustainability impact measurement and assessment

Different complementary methods can assist in measuring and assessing how circular goals and actions will impact social, environmental and economic aspects within and from the system in focus. The complementary methods can provide accepted indicators to measure and assess those sustainability impacts (e.g. adverse or beneficial). Guidance on applying complementary methods is described in Clause 8. Examples of complementary methods are included in Annex C.

7.4 Indicators and value

It is valuable to explore calculations of circularity indicators that contribute to retaining, recovering and adding resource value. It should be noted that the terms "adding", "contributing", "retaining" and "recovering" can result in negative values, i.e. value is lost.

Within the circular economy, value can be complex and difficult to measure, and requires careful consideration. This complexity arises because value represents not only the economic value of a resource or a product but also its environmental and societal value. Very often economic value does not reflect social or environmental impacts which can be associated with costs arising outside the system in focus.

EXAMPLE 1 The price of a plastic beverage bottle does not usually include costs due to collection, sorting, washing and recycling of discarded bottles and environmental pollution.

EXAMPLE 2 TV repair does not always represent an economic advantage for the manufacturer (where sales drive economic return) but is likely to represent significant environmental value (e.g. resource efficiency, waste decreases, avoiding toxic releases from landfill), economic value to the user (e.g. avoiding new purchase) and social value (e.g. local employment).

Circularity indicators can measure the degree to which circularity aspects of a product, process or operation (e.g. in an organization, value chain or region) are aligned with the objectives and principles of the circular economy. Critical to providing a meaningful assessment of resource value is the measurement of resource flows within the system in focus, and its inflow and outflow with the wider economic system. This can be used to estimate accurate economic value as well as provide input for environmental and social impact assessment.

EXAMPLE 3 Value calculation.

If a company is using materials with well-defined environmental values (e.g. embodied carbon, greenhouse gas (GHG) emissions, other releases), circular actions that reduce resource use can be used to calculate environmental value.

If 50 % of recycled material (r-plastic) is used (as estimated using A.2.3) and the GHG emissions of virgin plastic (v-plastic) and r-plastic are established at 2,20 CO_2e kg and 0,90 CO_2e kg per kg of the plastic, then the amount of GHG emissions is 1,55 kg per kg of plastic. The calculation is: 2,2 kg CO_2e (× 50 %) + 0,9 kg CO_2e (× 50 %) = 1,1 kg CO_2e + 0,45 kg CO_2e = 1,55 kg CO_2e.

The economic value of 1 ton of CO_2e emissions reduced can, for example, be calculated based on the international carbon emission trading system.

NOTE CO_2e indicates the CO_2 equivalent of total GHG emissions, i.e. includes gases other than CO_2 such as CH_4 normalized by its greenhouse warming potential.

Annex A provides additional calculation examples for core circularity indicators. Guidance and examples of assessing social, environmental and economic value are given in Clause 8.

7.5 Aggregation of circularity indicators

Complex systems can necessitate an aggregation of data from multiple systems or subsystems. Complex products or product portfolios often require data from various constituent components. Measurement can require data aggregation from external sources as well as internal sources. Aggregation can also be needed for higher system levels. The organization should ensure reliable aggregation in terms of the system boundaries, the indicators used, the source of data, the estimations and assumptions made.

See Annex G for additional information.

7.6 Data acquisition

7.6.1 Data acquisition steps

7.6.1.1 General

To acquire the data needed for the circularity measurement, the data acquisition steps A to E, as illustrated in Figure 8 and explained in 7.6.1.2 to 7.6.1.6, can be applied.

This flow chart is general to any data acquisition process. Whether measurements arise within the organization or external interested parties, the fundamentals of data traceability and verifiability apply. Be aware that challenges in acquiring the data can lead to adjustment of the selected indicators, boundary setting, and goal and scope.

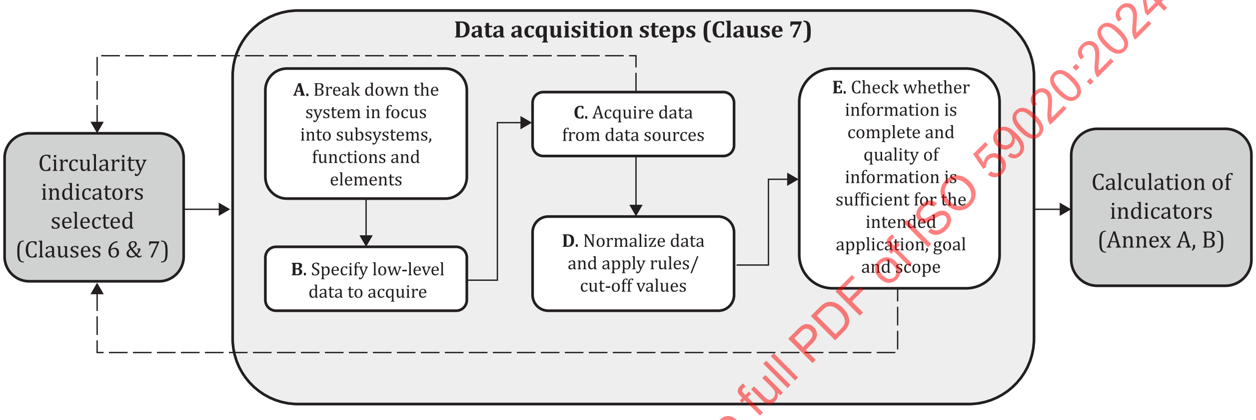


Figure 8 — Data acquisition process

7.6.1.2 Step A: Break down the system in focus

To enable a systematic data acquisition, and to provide transparency to the acquired data, it is recommended that the system in focus is subdivided into its elementary components for which data acquisition can be practically executed, such as the identification of data sources for general inflows and outflows.

This division of the system in focus into sub-processes can take the form of a graphic diagram, such as a process flow chart, that specifies all operations, processes and relevant actors and their exchange of resources (examples are provided in Annex H).

7.6.1.3 Step B: Specify low-level data requirements

After system breakdown and identification of general data sources, data are further specified with regards to the efforts needed and the degree to which it is feasible to acquire primary, specific or foreground data, and whether specific data acquisition approaches are needed or whether compromises need to be made in order to reach a complete set of data. The organization should decide and justify which data can be secondary, generic and background data.

This will often need data from external interested parties such as suppliers, business partners and resellers. These data should be clearly identified and mutually understood so that all parties involved are prepared to acquire and share the data.

7.6.1.4 Step C: Acquire data from data sources

For data that cannot be acquired with reasonable efforts, the consequences of missing data should be assessed. If the consequences are severe or the data are critical, the organization should consider the following to mitigate missing data:

— alternative acquisition approaches, such as modelling which provides techniques to derive the necessary data from theory or existing information;

— alternative ways to measure the indicator, e.g. by resource balance rather than direct measurement;

— use of background data, e.g. generic data for the sector or data adapted from another country (examples are provided in Annex F);

— choosing alternative indicators to avoid the need for specific and unavailable data.

This non-disclosure of data usually pertains to components and flows of the wider economic system that are outside the system in focus and can be owned and produced by external interested parties (e.g. suppliers).

7.6.1.5 Step D: Normalize data and apply rules and cut-off values

Data acquired should be balanced and normalized to the common denominator for the system in focus, such as "per provided function", "per product lifetime" or "per yearly production". All these transformations should be documented.

7.6.1.6 Step E: Check whether information is complete

Checking whether the information is complete includes, but is not limited to, checking whether for each acquired data item and each selected indicator:

— all data requirements presented under 7.6.2 are met;

— all data necessary to provide a truthful quantification of the total circularity aspect per unit of calculation per indicator and per the balanced quantification of the whole system in focus;

— all justifications, assumptions are updated and documented, are made available together with data, and reflect both the details and the total quantified result.

7.6.2 General requirements of acquired data

Acquired data should meet the following requirements:

— the data quality requirements established during the goal and scope, to meet the needs of the application of the result;

— the level of detail and specification implied by each individual selected circularity indicator;

— be representative, statistically, spatially and temporally consistent with the requirements of the selected circularity indicators, the economic system and the system in focus;

— strive towards being specific data based on primary data;

— be categorized as foreground or background, primary or secondary, specific or generic (secondary and generic data should be conservatively applied and not overstate the circularity);

— be acquired and supplied with sufficient documentation to enable verification of how well the data represent the above criteria, the reliability of its data source, any known data gaps, and other information of significance to the interpretation of the data;

— be supplied with justification with regards to how well the above criteria are met.

When the quality and reliability of the alternative data cannot be confirmed, they should be applied in a way that does not overstate the circularity performance and should only be used for internal decision-making.

EXAMPLE Data acquisition for an organization.

A beverage glass bottle manufacturing company wants to measure the circularity of its business operations. The boundary for the system in focus is set around the core operational activities, including both the activities within the boundary of the company organization as well as those outside. Activities inside the company organization include, for example, design, purchasing, manufacturing, sales, distribution and cleaning of bottles returning from the bottle take-back operation. Core operational activities outside the company boundary are, for example, logistics, the bottle take-back system, glass recycling, wastewater treatment and solid waste management. The bottles are manufactured in 15 plants across 3 continents. Data are acquired from three sources:

a) Data acquisition within the organizational boundaries: Data for production volumes of bottles are determined from sales statistics. Data for the amount of take-back bottles are acquired from internal logistics after the cleaning of take-back bottles as cleaning results in breakages. Data for the amount of procured glass for bottle-making is acquired from delivery orders. Temporal boundary is based on an average lifetime for a bottle after it is returned through the take-back or recycling system. The average lifetime is based on company internal statistics.

b) Data acquisition outside the organization: Data to calculate the share of glass that is based on virgin raw material is acquired from suppliers. The different production sites and the bottle markets have different technical possibilities and solutions for take-back systems, recycling, wastewater treatment, solid waste management, logistics and energy production. If the result of the measurement and assessment is intended for taking decisions for circular performance improvements, it can therefore be necessary to acquire locally specific data per each production site and each market where the products are sold, transported, waste managed, taken back, etc. The average lifetime of a bottle before it is returned through take back or recycling also depends on local differences.

c) Data acquisition for complementary methods: If the result of the measurement and assessment is also intended to consider climate change or resource consumption aspects, data can also be acquired to calculate carbon and water footprints. Data needed include, for example, emissions for transport (e.g. both outbound and inbound), energy used in glass bottle production, energy use for recycling of bottles and cleaning, as well as water consumption and wastewater treatment processes.

7.7 Documentation

Figure 9 summarizes the information items that should be documented to enable an end user to evaluate the data quality of the result of a measurement or assessment of circularity.

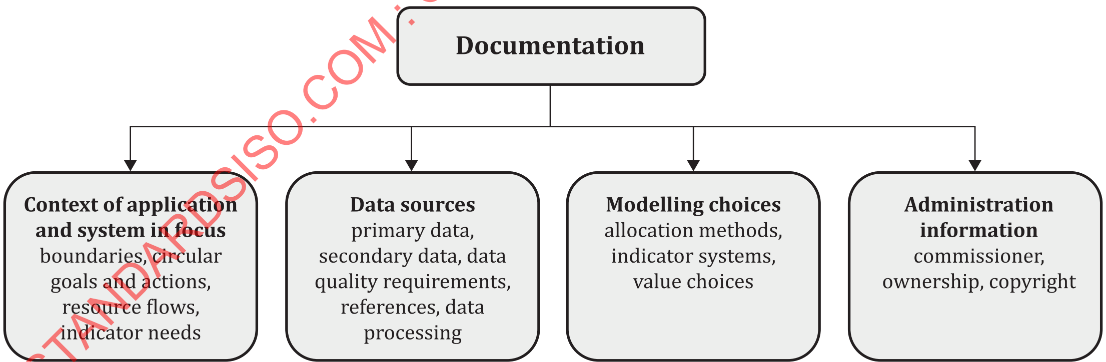


Figure 9 — Documentation to assess the quality

To enable and facilitate interpretation of the circularity performance and its accuracy, the documentation should include, but is not limited to, the following:

a) The context and application and system in focus:

1) the system level for the measurement and assessment;

2) the system in focus including nested subsystems, processes, functional units, locations, etc.;

3) the boundaries of the system in focus including spatial and temporal boundaries;

4) the circular goals and actions and related circularity aspects to be measured;

5) the types, properties, amounts and other significant qualifications or quantifications of resource flows;

6) the economic, social or environmental forces that can influence the circularity performance.

b) Data sources:

1) references for the sources of data;

2) description of how data have been acquired (typically measurement, statistically aggregated measurement data, mathematical modelling based on statistical data, mathematical model based on design data, or combinations thereof);

3) metadata to distinguish between "verified" and "not verified" or "validated" and "not validated" data;

4) situational influences of the data used in the analysis (such as territorial, seasonal and sectoral);

5) description of how data have been processed;

6) informed data quality statements made by the practitioner.

c) Modelling choices:

1) allocation methods used to separate the system in focus from the wider system, cut-off limits and any other choices relevant to setting system boundaries;

2) system of indicators used to quantify the measurement and assessment;

3) relevant interfaces with social, environmental or economic systems.

d) Administrative information:

1) relevant facts about the reasons and decision to carry out a measurement and assessment of the system in focus;

2) ownership of data;

3) date of publication;

4) copyright.

8 Circularity assessment and reporting

8.1 Assessing circularity criteria

In conducting the assessment, the organization is required to review the application of:

a) the circular economy principles in ISO 59004;

b) the principles of measuring and assessing circularity in Clause 4;

c) the core circularity indicators of Clause 7, Table 3 and guidance from Annex A.

Circularity assessment involves the evaluation and interpretation of results from circularity measurements to determine the circularity performance of the system in focus. The circularity performance is the degree to which a set of circularity aspects align with the core objectives and principles of a circular economy.

LCA should complement the information provided by the circularity indicators, providing any additional data needed to account for linear resource consumption and non-circular resource outflows (although the RFA and the life cycle inventory (LCI) should provide similar information), as well as environmental and social impacts from resource extraction and resource losses occurring inside and outside of the system in focus.

The assessment should consider contributions and potential conflicts/trade-offs to sustainable development, because social, environmental and economic impacts can inherently be linked to the circular goals and actions of the organization.

Complementary methods can be useful instruments when conducting the measurement and assessment. Existing methods, approaches, guidelines or standards can be applied to complement the circularity measurement and assessment.

EXAMPLE The UN Agenda 2030[54] serves as a complementary method in determining the impacts on the SDGs.

Annex C provides examples of complementary methods.

8.2 Steps for assessing circularity performance

Figure 10 summarizes the individual steps required to assess the circularity performance:

— review findings and usefulness of the measurement results;

— include considerations based on results from complementary methods;

— consult interested parties, users and target audiences;

— document and report the circularity performance assessment outcome.

The first three steps can be reiterated when needed. The steps will be informed by relevant information from this document, ISO 59004, ISO 59010, ISO 59014 and ISO 59040.

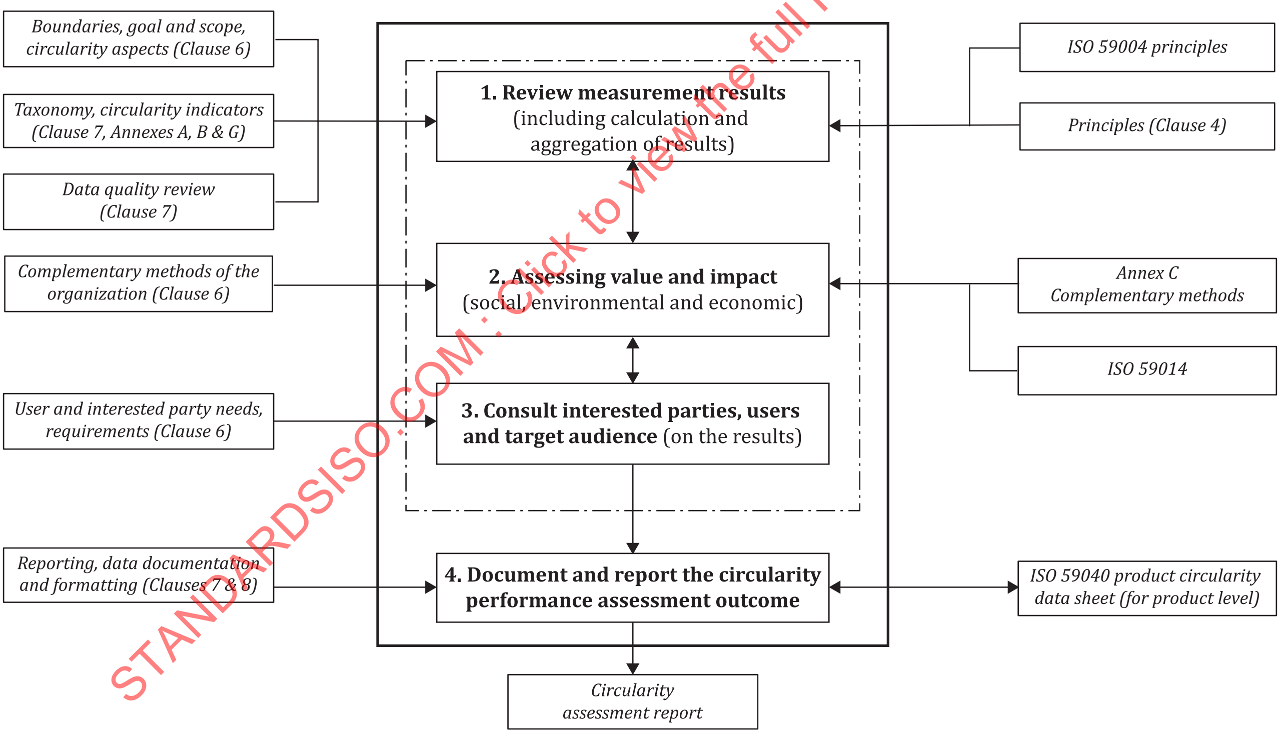


Figure 10 — Steps for assessing circularity performance

8.3 Step 1: Review measurement results

In reviewing the measurement results, the following aspects should be interpreted:

— To what extent can the circular goals and outcome of the actions be measured?

— What worked well in setting the boundaries of the system in focus and what were the limitations?

— To what extent can the circularity indicators be measured and what indicators were used?

— What indicators and measurements provide results that are useful to guide decisions and improve the achievement of the circularity goals?

— What calculations or aggregations were used, and can the results be used for internal or external benchmarking?

— Which of the principles from ISO 59004 were applied, which were not and why?

— Which of the principles from Clause 4 were applied, which were not and why?

— To what extent can the quality requirements of the primary and secondary data used in the measurements be met and which cut-off criteria were useful? And what are the gaps in acquiring data and information?

— Are there risks for unintended or indirect impacts identified that merit additional analysis?

To be transparent, the processes, procedures, methods, data sources and assumptions for providing and generating information should be made available to all relevant interested parties, by using formats, language and media that meet their expectations and needs. This also covers the accessibility of metadata, documentation and support services.

8.4 Step 2: Assessing value and impact

8.4.1 General

While assessing the circularity performance, a broad perspective of sustainability should be considered to maximize the contribution to sustainable development.

The organization can apply existing methods, approaches, guidelines or standards (i.e. summarized as “complementary methods”) to:

— measure additional circularity aspects;

EXAMPLE 1 On the product level with LCA and on resource flows with MFA methods and International Standards (e.g. ISO 14053).

— assess social, environmental and economic impacts and values.

EXAMPLE 2 With standards on social responsibility (e.g. ISO 26000), environmental topics (e.g. the ISO 14000 family of standards) and economic aspects (e.g. life cycle costing (LCC) methods).

Complementary methods can provide standard indicators to measure and assess sustainability impacts. Annex C provides more detailed information on complementary methods with criteria of selection, ISO standardized methods and other methods (e.g. developed by the UN and the OECD[51]).

EXAMPLE 3 Sustainability impacts:

a) Social: Changes in resource use can affect local and national employment patterns positively or negatively. For example, local communities dependent on resource mining as a source of employment can be impacted as resource demand decreases. Alternatively, new job opportunities can arise when repair and recycling approaches are increasing. Better disassembly of products and components can improve the working conditions of workers while circular design and reuse of products and solutions can benefit consumers.

b) Environmental: Increased use of wood as a renewable resource can result in harvesting forests too quickly and damage to their ecosystems. Reducing waste to landfill can avoid pollution of soil and ecosystems.

c) Economic: Changes in resource use can have positive or negative effects on costs of products and solutions. Circular actions for repair, refurbish, remanufacture and repurposing can affect prices of renewable and non-renewable resources.

NOTE Socio-economic impacts refer to the effects that economic activities and social conditions have on a community, society or the overall well-being of individuals. These impacts can include changes in employment, income distribution, living standards, access to resources and overall quality of life.

There are often trade-offs between economic, environmental and social value or trade-offs among economic aspects, environmental aspects or social aspects. For this reason, it is important to consider all aspects and weigh them on a case-by-case basis. Often the economic values are well considered, but environmental and social aspects are not, or are not assessed sufficiently. A holistic and long-term perspective will help to find the most sustainable approach.

EXAMPLE 4 Cases with potential trade-offs:

— Shop subscription for sharing of clothes: A new need is created to regularly wear something different which can be less environmentally friendly than the prolonged use of the same clothes available at home.

— Replacement of a fossil-based raw material with a renewable material for the production of plastics: The material could have been used as food (e.g. in the case of corn) or the large-scale cultivation of the biomaterial can damage biodiversity. Using biomaterial from low value sources or waste can avoid such conflicts.

— Re-use of construction materials: Re-use conserves entire products and the energy and GHG emissions that had already been invested for the production of the material. However, if the new destination of use is far away, additional transport emissions are created. Choosing local re-use destinations keeps transport emissions low.

8.4.2 Economic value

An economic assessment quantifies the economic performance of a circular approach or circularity action. The assessment delivers an important basis for decision-making (e.g. to implement a circular value creation model, to purchase a product with circularity aspects instead of a linear one).

The organization can apply methods that consider all costs and benefits that will be incurred during the life cycle of the products. Indicators and methods for the assessment of economic value can be found in Clauses A.6 and B.6, and in Annex C.

LCC is a complementary method (see Annex C) that can be used to analyse the costs. LCC includes:

a) total cost of ownership (TCO), which includes:

   1) purchase price and all associated costs (e.g. packaging, delivery, product damages, installation, insurance);

   2) operating costs, including energy, fuel and water use, consumables, spares and maintenance;

   3) end-of-life costs, such as decommissioning or disposal;

b) positive or negative impacts to society and environment that can be quantified in monetary value (e.g. ISO 14008).

8.4.3 Retaining economic, environmental and social value

Within a closed loop system, resource value can be retained by a circular flow of resources by actions such as reuse or remanufacturing. However, these can result in substantial changes in value, as described below, which reflect the complex nature of value. The calculation of indicators in this category requires correctly quantifying the resource flows, such as amounts of flows per unit time, amounts of releases and amounts of losses. Properly considered resource flows can be used to estimate the resulting economic, environmental and social impacts.

Important considerations are:

— economic benefits due to improved innovation and competitiveness, as well as economic cost comparisons between virgin, recovered, renewable and non-renewable content, and cost savings due to reduced resource use and distribution costs;

— environmental benefits of reduced virgin resource use, based on multi-criteria LCA;

— societal benefits include, for example, healthy benefits due to less (chemical) pollution, increased employment of local workers, and improved quality and consumer experience;

— quality of data used when calculating a quantitative indicator is imperative and should represent the same time frame, geographical representation or other monitoring of circular actions as intended by the measurement.

Indicators for retaining resource value are detailed in Table 2, such as “Per cent actual reused products and components derived from outflow”.

EXAMPLE Value of recycled glass.

In some countries, more than 90 % of all glass bottles are recycled. The cullet (i.e. recycled glass) is mixed with virgin material to produce new bottles. The economic cost of a recycled and virgin glass bottle can be similar because of the manufacturing costs. However, a recycled glass bottle has environmental life cycle impacts that can be considered versus alternative bottle materials, such as avoiding sand extraction, washing, dye production for coloured glass and other processing. There are also waste and landfill costs which are avoided in the circular approach. This means that the net value of recycled glass can be higher than virgin glass, despite similar process and manufacturing costs.

There are often trade-offs between economic, environmental and social value. For example, if the recovery, treatment, recycling technologies add considerable expense or are associated with high environmental burdens (e.g. GHG emissions) and or poor social outcomes (e.g. lower employment, land use), the net value can be lower.

8.4.4 Adding resource value

Within loops where used product components, resources or waste flows that have not been used are subsequently used within different product or process cycles, the resource value can be increased or decreased. Value should be holistically assessed rather than simply assessing economic value.

Adding resource value can be affected in different ways, with fundamentally different calculation requirements. To accurately calculate the overall added system value, it is important to set the system boundaries to include the phase of use in products with a higher economic value.

8.4.5 Recovering resource value

Recovering resource value can be described as utilizing resources from materials or products at an end-of-use cycle that otherwise can be discarded and treated as waste. At this point, a recoverable resource turns into a recovered resource. Also, a former non-recoverable resource can be turned into a recoverable resource and be effectively recovered, once any technological, economic and regulatory constraints that prevented its utilization have been overcome.

EXAMPLE The resource value is increased when waste wood products such as lignin are recycled into high value carbon fibres.

A holistic examination of resource value for treatment or recovery compared to treating the resources as waste needs careful attention. Complementary methods for measuring GHG emissions, embodied carbon and energy balance have relevance to estimating whether recovery processes have a positive or negative value.

8.4.6 Comparability on environmental and social impacts

The outcome of the measurement and assessment process represents the situation of the system in focus at a particular time representing data for a particular time interval. To determine changes over time, the organization should repeat the measurement and assessment periodically, using the same methodologies over a similar time interval. Care should be taken in the selection of the period for which a measurement and assessment takes place (e.g. annually, monthly, weekly) and the period between repeated measurements and assessment so that the results are representative and meaningful. The comparability of the different outcomes from the same system in focus should be considered, due to changing conditions in the system in focus and its system boundaries.

Variability in data sources, calculation methods or assumptions can make two systems not comparable, even with all other circularity aspects being equal. Assessment outcomes should not be used to make simplistic comparative claims, such as “region, organization or product A is more circular than region, organization or product B”, as the complexity of the outcomes precludes this type of conclusion.

8.4.7 Environmental comparability

In comparing environmental impacts (e.g. for benchmarking, claims or reporting), an organization should act in a transparent manner. Circular assessment reports can be useful in benchmarking one's organization's findings against existing findings, to identify improvement possibilities.

Environmental claims should be based on critically reviewed LCA studies following the guidelines from ISO 14040 and ISO 14044, whenever possible. An organization should also apply the following recommendations:

— refer to ISO 14021 for guidance on self-declared environmental claims;

— environmental claims should be supported by documented data with transparent assumptions made known;

— environmental claims should reflect the achievement of the circular goals.

When communicating the results for an environmental claim:

— avoid selective communication of the results of a circular assessment study, because choosing to disclose certain results of a circular assessment study, while not disclosing all the findings of that study, can result in ineffective and potentially unethical communications;

— beware of greenwashing: do not use results out of context, be transparent and make sure your environmental claims can be substantiated;

— review environmental claims in your region (e.g. the US Federal Trade Commission (FTC) has recommendations on how to make environmental claims, with examples of specific words that are and are not acceptable).

8.4.8 Social comparability

In comparing social impacts (e.g. for benchmarking, claims and reporting), an organization can classify interested party categories and impact categories for reviewing social aspects of the life cycle approach.

For example, interested party categories and corresponding impacts can be:

— workers: labour practices and health and safety with regard to recycling activities;

— local communities: socio-economic development and health and safety;

— suppliers: socio-economic repercussions on, for example, circular design and logistics.

— consumers: health, safety and social benefits of circular products and services (e.g. mobility as a service).

8.4.9 Economic comparability

Changes in resource use can negatively or positively affect local and national employment patterns. Circular actions for repair, refurbish, remanufacture, recycle can create new employment opportunities. There are positive social benefits to adopting a circular economy, not only negative consequences.

Changes in resource intensity can affect local and national employment patterns, creating successful new companies in various sectors while also creating new places for investment. This can draw some people away from previous employment fields into new employment opportunities. Circular actions such as repairing, refurbishing, remanufacturing and recycling can incentivize the creation of new jobs and can impact the price of resources in different ways than they would impact the price of those resources in a linear economy. Some resources can prove to be more valuable in a circular economy and some can prove to be less valuable.

8.5 Step 3: Consult interested parties, users and target audiences

In consulting interested parties, users and target audiences, the following needs and requirements should be reviewed:

— how the measurement and assessment results support the circular actions and decision-making of internal interested parties associated with the system in focus;

EXAMPLE From design, procurement, production, service, repair, assembly, logistics, finance, legal, sales and disassembly.

— how the measurement and assessment results support the external interested parties involved or affected, such as suppliers, customers, consumers, governments, recycling companies, business partners, non-governmental organizations (NGOs), local communities, and representatives of traditional knowledge, native ecosystems and future generations.

8.6 Step 4: Document and report the circularity performance assessment outcome

8.6.1 Transparency towards interested parties

After finalizing the circularity assessment, communication of the results should consider the needs of the target audience. Tables and figures can be used to help illustrate the resource flows and resource values as well as environmental and social impacts. Ultimately, the presentation of a circularity assessment should enable a good understanding of the performance while providing full transparency regarding uncertainties and data gaps.

In documenting the circularity performance outcome of the core circularity indicators of Annex A and other indicators (see Annex B), the organization should include the best available information to summarize all resource inflows and outflows including non-circular flows of the system in focus. The information should be described in terms that reflect interested parties' interests and should consider at least:

a) resource volumes (resource mass balance);

b) resource values;

c) resource quality.

Separate accounts should document energy flows and flows and qualities for water, and non-renewable and renewable resources. All non-circular outflows should be documented using consistent units clearly related to the input amounts.

8.6.2 Verifiability of information

Verifiability of all data documentation is a key criterion to ensure transparency.

This verification is carried out to ensure a proper interpretation of the results and to give explicit reasons for any extrapolations, simplifications or modelling performed, considering the confidentiality of information, if required. In addition, any volatility or uncertainty should be disclosed. When using a chain of custody model to allocate resources, the organization should report the chosen model alongside the resource flows to which it was applied.

8.6.3 Formatting

The assignment of information into the data documentation is referred to as "formatting" and includes:

— interpretation and assessment of the original information in terms of the scope of the data documentation format;

— structuring the original information;

— entering the structured information.

The following recommendations apply to formatting:

— Information should be entered into the appropriate metadata.

— The data documenter should ensure that all data related to the system measured and assessed that are of importance for circularity measurement are adequately transcribed and that no bias is generated. Justification and documentation should be made regarding information that has been neglected or modified.

For more information, see Annex F.

8.6.4 Reporting on hazardous substances

The circular economy will only be sustainable and successful if materials can be safely reused, recycled, remanufactured or repurposed. The use or creation of a by-product of a substance considered to be hazardous can have impacts on the quality of reuse and recycling and therefore on the success of value retention.

A substance is considered hazardous when it can adversely affect human health or the environment. The regulatory restriction of specific hazardous substances varies from country to country, as the determination of risk varies.

Selecting materials and substances with low hazard profiles is important in a circular economy as these can be kept in use for a longer time without causing harm. Product designers should therefore consider the impact of materials and chemicals they select to encourage safe and sustainable use in a circular economy. Avoiding the introduction of hazardous substances into materials or products reduces potential risks. Organizations responsible for recycling, recovery and recirculation should request information on the chemical composition of materials received or collected in order to ensure correct handling and treatment and lower the risk of mismanagement.

Material declaration methods and tools can be used to communicate hazardous substance information through the value chain. For example, IEC 82474-1 provides a cross-sector standard for collecting and exchanging information on substances and materials in a product. The use of such an International Standard helps ensure that all actors in the value chain are using common protocols to identify, report and interpret information on hazardous substances.

Annex A
(normative)

Core circularity indicators and data measurement

A.1 Overview

A list and description of core circularity indicators that shall be considered for circularity measurement and assessment are provided in this annex. Not all of the core resource inflow circularity indicators are necessarily applicable at each system level or every type of system. In cases where an indicator is not applicable, it can be counted as zero or declared as “not applicable (N/A)”, explaining why it is not applicable. If the relevant data are not available, they should be counted as zero.

The circularity indicators are grouped into categories such that material, water and energy aspects are analysed separately. This separation is done given that water and energy both have unique aspects that should be measured to determine circularity performance.

Many of the indicators provide percentage values (e.g. “average per cent reused content of an inflow”). However, in calculating these percentages, absolute values with units should also be documented. This allows the scale to be properly assessed and data to be aggregated.

A.2 Resource inflows

A.2.1 Introduction to resource inflow circularity indicators

The resource inflow circularity indicators represent the circularity performance of resources that flow through the system boundary into the system in focus. All resource inflows except water and energy (which are addressed in separate categories) shall be accounted for in this category.

Resource inflows are measured to quantify four types of content:

a) reused content;

b) recycled content;

c) virgin, renewable content;

d) virgin, non-renewable content.

These four types of content are intended to be mutually exclusive and add up to represent 100 % of the resource inflow (see Figure A.1). The first three types (recycled, reused and virgin, renewable content) are considered as circular; whereas the fourth type (virgin, non-renewable content) is the remaining portion that is from a non-circular source. The non-circular (linear) inflow can be calculated by subtracting the circular inflows from 100 %. For a material to be described as a “renewable material”, it shall adhere to the specific conditions described in A.2.4.

NOTE 1 Recycled content and reused content can be derived from either renewable or non-renewable resources. For example, recycled paper can be derived from renewable material and recycled plastic derived from non-renewable materials.

NOTE 2 The designation of exactly what qualifies as renewable content can be complex. In the use of this document, detailed understanding of the term “renewable content” is specified in A.2.4.

NOTE 3 The resource inflow circularity indicators take only the source of the resource into account and do not capture whether the resource is recoverable at end of life. The potential recoverability of resources at end of life is considered in the outflow indicators (see Clause A.3) and not when measuring the inflow indicators.

NOTE 4 It is important to consider the circular inflow indicator with the circular outflow indicator, so that increase in circular content does not compromise the ability to recover or recycle the product component at the end of a use.

In cases where the resource inflow circularity indicator is not relevant, it can be counted at a value of zero. If the organization is responsible for recovering materials to convert them into recycled or reused materials, the organization can measure and report the recovered material. However, the recovered material does not count as recycled content or reused content unless it meets the requirements and guidance specified in A.2.2 and A.2.3

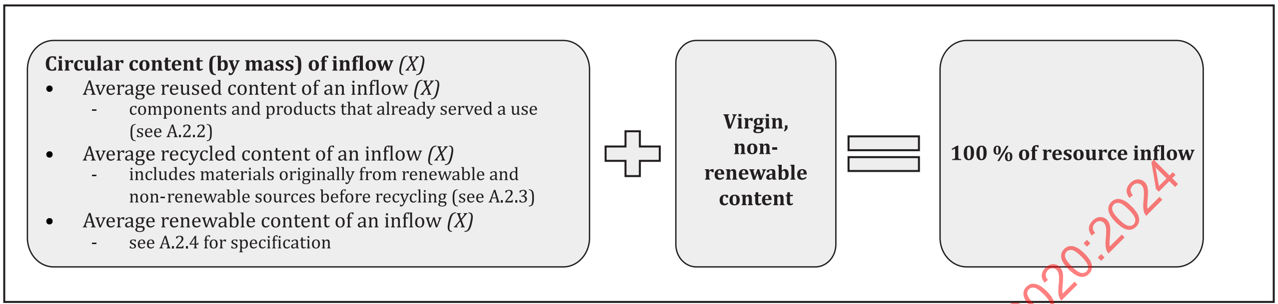


Figure A.1 — 100 % resource inflow formula

The designation of an inflow or a fraction of it as one of the circular types of content should be documented with evidence to demonstrate that the level of circularity content is not overstated. If there is ambiguity or uncertainty about which type of content is applicable, the user should decide based on the available information and document the rationale.

Different types of inflow resources or those that have different circularity characteristics (e.g. have different amounts of recycled content) should be measured and recorded separately. In Figure A.1, the "*X*" in inflow (*X*) represents a specific resource inflow.

The calculation of the circularity indicators for each inflow can be performed and reported individually or can be aggregated, based on the goal of the circularity measurement and assessment and allowing for attributed content from a mass balance chain of custody model as defined in ISO 22095. Maintaining separate calculations for each resource inflow (*X*) enables characteristics such as per cent reused content to be tracked through use and processing stages within the system in focus. It also provides flexibility in applying complementary methods for circularity assessment.

All resource inflows that have a significant impact on the circularity performance as defined by the goal and scope should be included.

A.2.2 Average reused content of an inflow (*X*)

The "average reused content of an inflow (*X*)" circularity indicator represents the average fraction of an input material resource (*X*) that is reused. A resource inflow is reused if it has already served a use. It can include materials and parts but does not include materials that have been processed through a recycling operation.

When a product that has reached the end of its useful life is remanufactured, the reused parts and materials do qualify as reused content in the remanufacturing process. Here, the product is remanufactured, typically using some new material and parts, to produce a like-new product that meets all of the performance and durability expectations of a new product. The flow of materials and parts from the old product that are not reused in the remanufacturing process should be tracked and measured within the system in focus. If they are reused in other manufacturing processes, they qualify as reused content for those processes, or if they are transferred outside the system in focus, they should be addressed as a resource outflow.

The calculation of the circularity indicator is performed by applying Formula (A.1):

$$\%_{\mathrm{REUI}(X)} = \left(\frac{m_{\mathrm{REUI}(X)}}{m_{\mathrm{TI}(X)}} \right) \cdot 100 \qquad \text{(A.1)}$$

where

$\%_{\mathrm{REUI}(X)}$	is the average reused content of an inflow (X), in %;
$m_{\mathrm{REUI}(X)}$	is the mass of reused components and products of an inflow (X), in kg or other mass unit;
$m_{\mathrm{TI}(X)}$	is the mass of total input material of an inflow (X), in kg or other mass unit.

A.2.3 Average recycled content of an inflow (X)

The "average recycled content of an inflow (X)" circularity indicator represents the fraction of input resources that is confirmed as recycled material. A material qualifies towards recycled content if it meets the specification of recycled content in ISO 14021. This includes pre-consumer and post-consumer material. It specifically excludes reutilization of materials within an industrial process such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it. In addition to the physical average method or proportional allocation, the mass balance chain of custody model as identified by ISO 22095 (see A.2.1) can also be used.

Existing horizontal or sector-specific standards should be used when available to calculate the recycled content. For example, for energy-related products, EN 45557 should be applied.

The calculation of the circularity indicator is performed by applying Formula (A.2):

$$\%_{\mathrm{RECI}(X)} = \left(\frac{m_{\mathrm{RECI}(X)}}{m_{\mathrm{TI}(X)}} \right) \cdot 100 \qquad \text{(A.2)}$$

where

$\%_{\mathrm{RECI}(X)}$	is the average recycled content of an inflow (X), in %;
$m_{\mathrm{RECI}(X)}$	is the mass of recycled material of an inflow (X), in kg or other mass unit;
$m_{\mathrm{TI}(X)}$	is the mass of total input material of an inflow (X), in kg or other mass unit.

If a resource flowing through the system boundary into the system in focus contains a portion of recycled material, the portion can be used directly as the calculated circularity indicator value for the resource. Alternately, the mass that is recycled material can be calculated and then aggregated with other similar resources to calculate the recycled content for all similar resources.

Where possible, the fractions that are pre-consumer and post-consumer content can be disaggregated.

A.2.4 Average renewable content of an inflow (X)

The "average renewable content of an inflow (X)" circularity indicator represents the fraction of a resource inflow (X) that meets the conditions specified for renewable material below. For the purpose of calculating this indicator, renewable material is virgin biomass that fulfils the following criteria:

— replenished at a rate equal to or greater than the rate that it is extracted;

— sourced or managed in a manner compatible with sustainable development;

— produced with regenerative practices, at a minimum sustainably grown or managed, so that the services provided by these resources and other linked resources remain available for future generations.

Regenerative production uses practices that support biodiversity and continued provision of ecosystem services, especially soil fertility, water purification and regulation and carbon sequestration.

Relevant information on the criteria or verification method that was used to assess the regenerative or sustainable sourcing should be disclosed (e.g. by documenting standard(s) or methods that ensure that biomass is responsibly sourced from sustainably managed lands).

The calculation of the circularity indicator is performed by applying Formula (A.3):

$$P_{\mathrm{RENI}(X)} = \left(\frac{m_{\mathrm{RENI}(X)}}{m_{\mathrm{TI}(X)}} \right) \cdot 100 \tag{A.3}$$

where

$P_{\mathrm{RENI}(X)}$ is the average renewable content of an inflow (X), in %;

$m_{\mathrm{RENI}(X)}$ is the mass of renewable material of an inflow (X), in kg or other mass unit;

$m_{\mathrm{TI}(X)}$ is the mass of total input material of an inflow (X), in kg or other mass unitg.

A.3 Resource outflows

A.3.1 Introduction to resource outflows circularity indicators

The resource outflow circularity indicators represent the circularity performance of resources that flow out of the boundary of the system in focus. All resource outflows, including secondary materials produced (see ISO 59014) except water and energy (which are addressed in separate categories), should be accounted for in this category. This includes outflows accounting for non-recoverable resources (e.g. hazardous waste, for which specific treatment or disposal with no recovery possibility is required) and emissions and other resource outflows that have a significant impact on the circularity performance (as defined by the goal and scope).

The following three core circularity indicators are intended to represent outflows that are mutually exclusive and represent the circular outflows:

— components and products that are reused (see A.3.3);

— per cent recycled material derived from outflow (see A.3.4),

— products and materials for renewable recirculation (see A.3.5).

The remaining outflows are considered as linear and do not count towards circularity. The linear (non-circular) outflow can be calculated by subtracting the circular outflows from 100 %.

The sum of the circular outflows and the remaining non-circular outflows represent 100 % of the resource outflows from the system in focus, see Figure A.2. The resource outflow circularity indicators specified in A.3.3, A.3.4 and A.3.5 shall be calculated and documented. In cases where the circularity indicator is not relevant, it can be counted at value zero. The circularity indicators for each outflow can be calculated and reported individually or they can be aggregated, based on goal and scope.

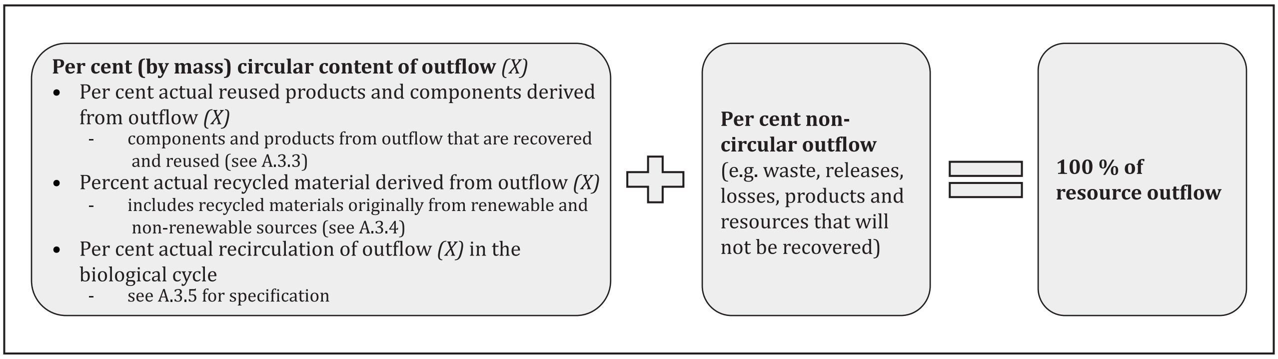


Figure A.2 — 100 % resource outflow formula

Maintaining separate calculations for each resource outflow (X) provides for more flexibility in performing a circularity assessment including the use of complementary methods as part of that circularity assessment.

Outflows from the system in focus that are considered non-circular (waste, releases, losses, non-recoverable products) should be mapped to resource outflows for the purpose of circularity measurement and assessment (see Annex E for additional considerations and guidance on non-circular outflows). All significant non-circular outflows should be identified and calculated separately including for solid waste, releases, losses and non-recoverable products. If any of these resource outflows are known to be recycled, reused or subject to renewable recirculation, then the applicable core circularity indicators described in A.3.3, A.3.4 and A.3.5 shall be calculated. Otherwise, these outflows are considered linear (recorded as 0 %) as they are non-circular outflows incurred by the system in focus.

The circularity indicator A.3.2 on average product life is applicable to only certain types of systems in focus (e.g. products manufacturing) and is not mandatory to calculate. It can be measured and calculated with a different temporal boundary (i.e. product end of life) than other resource outflow circularity indicators which are typically measured when the resource leaves the system boundary.

A.3.2 Average lifetime of product or material relative to industry average

The "average lifetime of product or material relative to industry average" circularity indicator identifies the degree to which a resource outflow (e.g. a product or material) is able to retain its value over time compared to the industry average for that resource when available. This can be used to represent the slowing of a resource flow. This circular indicator can be particularly relevant when the system in focus produces products or materials that are then provided to a user to fulfil a function.

To calculate this circularity indicator, the (useful) expected lifetime of a product or material is represented by its durability. Durability is determined using a technical assessment method that takes into consideration the reliability of the product or material and possibilities for lifetime extensions from performing maintenance, repair, updates and refurbishing (as applicable for the product) throughout its expected lifetime.

Durability assessment takes into consideration all the appropriate steps to maintain the product or material in a state where it performs as intended (for the initial user and for product reuse).

All resource inflows required for maintenance, repair and updates to achieve the specified durability shall be measured or estimated and accounted for in the circularity measurement and assessment. Energy and water should also be considered. Energy use for maintenance, repair, etc. apply to the energy indicators and not to the resource inflow and outflow indicators.

The methodology to calculate the lifetime of a product varies depending on the type of product. The industry average lifetime of products is currently not generally available, but there are several examples of practices where such information has been compiled and made available that can be used for the calculation, including:

— sector standards, including national standards and codes, that address performance or quality on products (e.g. construction products and buildings performance);

— commercial consumer-guarantee-related directives or formal agreements (e.g. the EU Directives for empowering consumers for the green transition through better protection against unfair practices and better information);

— verifiable third-party environmental labelling (e.g. an environmental product declaration (EPD) from ISO 14025);

— publicly or commercially available product life databases;

— International Standards regarding service-life planning (e.g. the ISO 15686 series, especially ISO 15686-8).

Opportunities and steps to extend the lifetime of a product can be complex and interrelated. Therefore, it is important that a holistic approach is taken and trade-offs are considered using appropriate complementary methods or guidelines that are relevant to the type of product when assessing durability. For example, trade-offs should be considered when assessing reliability versus reparability and other lifetime extension factors.

For energy-related products, EN 45552 and EN 45554 can be relevant in identifying aspects or considerations to help sectors specify a methodology to calculate the average lifetime relative to industry average.

The calculation of the circularity indicator is performed by applying Formula (A.4):

$$R_{\mathrm{LP}(X)} = \frac{t_{\mathrm{LP}(X)}}{t_{\mathrm{IALP}(X)}} \quad \text{(A.4)}$$

where

$R_{\mathrm{LP}(X)}$ is the lifetime ratio of a product or material (X); it is dimensionless;

$t_{\mathrm{LP}(X)}$ is the lifetime of a product or material (X), in, for example, years;

$t_{\mathrm{IALP}(X)}$ is the industry average lifetime of a product or material (X), in, for example, years;

A.3.3 Per cent actual reused products and components derived from outflow (X)

The “per cent reused components and products derived from the outflow (X)” circularity indicator is a calculation of the fraction of outflow(X) that was recovered or will be realistically recovered from the outflow (at end of life) for reuse in the production, maintenance or repair of other resources or products.

When a predicted reuse amount (or reuse rate) is used in the calculation for outflows (e.g. for products which will first serve a useful life and then be considered for reuse and recycling at end of life), it shall represent realistic expectations of reuse to avoid overstating the reuse amount. The assumptions and information on historical reuse rate that are used in establishing reuse expectations should be documented.

For energy-related products, EN 45554 can be relevant in calculating the per cent actual reused components and products derived from output flow. EN 45554 specifies requirements for identifying priority parts for reuse.

For product outflows, if an end-of-life treatment scenario (as described in EN 45554) has been developed for the product category, such scenario can be used in determining the reuse rate.

The calculation of the circularity indicator is performed by applying Formula (A.5):

$$P_{\mathrm{REUO}(X)} = \left(\frac{m_{\mathrm{REUO}(X)}}{m_{\mathrm{TO}(X)}} \right) \cdot 100 \quad \text{(A.5)}$$

where

$P_{REUO(X)}$ is the actual reused products and components derived from outflow (X), in %;

$m_{REUO(X)}$ is the mass of outflow (X) that is reused, in kg or other mass unit;

$m_{TO(X)}$ is the total mass of outflow (X), in kg or other mass unit.

A.3.4 Per cent actual recycled material derived from outflow (X)

The "per cent actual recycled material derived from outflow (X)" circularity indicator represents the effective level of recovering materials from resource outflows obtained through a combination of collection and recycling.

It is a calculation of the average fraction of recycled material that is derived from the resource outflow after it has completed the recycling process. If the recycling will take place in the future, the amount of recycled material may be forecast based on actual or industry average data from similar products in the applicable regions. The data should be indicative and not overstate the recycled material derived from outflow(X) that will be achieved.

The intention of this circularity indicator is to provide a quantitative and verifiable measure of the amount of material that has been obtained, following a collection or recovery process, from a recycling process and can be used in new products. It represents the actual amount of material that goes from one use cycle into another.

This circularity indicator can accommodate both renewable and non-renewable materials.

The actual amount of recycled material from the products in the system can vary significantly based on the ability to dismantle the product, the available recycling infrastructure and recycling technologies, and the suitability of the product parts and materials for recycling into high quality materials. Calculation of actual recycled material derived can be complex and can benefit from reference to a product category specific end-of-life treatment scenario. Product recovery and recycling can involve multiple steps performed by several organizations. These value chain actors can have interest in understanding the actual recycled material derived from the outflow sent through the full recycling process. Gathering these data can require users to develop relationships with other value chain actors responsible for recycling material into new material.

Actual data of recycled material derived from products at end of life should be used whenever possible. If product-specific data are not available, industry average data for the product category based on the end-of-life treatment scenario and region can be used. A conservative approach should be used in selecting data to ensure that the recyclability rate is not overstated. The assumptions and information on historical recycling that are used in establishing recycling expectations should be documented.

If traceable recyclability data are not available for a specific resource outflow, 0 % should be recorded.

The calculation of the circularity indicator is performed by applying Formula (A.6):

$$P_{RECO(X)} = \left(\frac{m_{RECO(X)}}{m_{TO(X)}} \right) \cdot 100 \qquad \text{(A.6)}$$

where

$P_{RECO(X)}$ is the per cent actual recycled material derived from outflow (X), in %;

$m_{RECO(X)}$ is the mass of recycled material derived from outflow (X), in kg or other mass unit;

$m_{TO(X)}$ is the total mass of outflow (X), in kg or other mass unit.

A.3.5 Per cent actual recirculation of outflow (X) in the biological cycle

The "per cent actual recirculation of outflow (X) in the biological cycle" circularity indicator represents the fraction of outflow (X) that is recirculated at end of life for safe return to the biosphere (biodegradation) and meets the qualifying conditions for recirculation (e.g. composting or anaerobic digestion). The returns to the biosphere can be described as a fully biodegraded material or substance that microorganisms can decompose and that degrades to organic molecules that living systems can use further (e.g. via composting and anaerobic digestion).

Organizations can also refer to existing testing standards on biodegradability and compostability such as ISO 15270, ISO 17088 or ASTM D6400. When considering the circular flow of resources, preference should be given to biological material that is compostable in either industrial or domestic settings as the material will have a higher likelihood of contributing to regenerate ecosystems.

Additionally, reference of the resource management actions is recommended when considering further use of outflows (e.g. reuse, repurposing, recycling or cascading of the material can be preferred to biodegradation as long as it maintains the highest value of the outflow resource). As described below, other possible uses of outflows can prevent the material from qualifying as renewable recirculation.

The foremost condition for renewable recirculation is that the material and products of the process are not detrimental to the water, soil or biodiversity of ecosystems in which they are introduced.

Qualifying conditions for renewable recirculation methods are as follows:

— The material originates from a biological source or can be broken down on a molecular level by microorganisms or fulfils criteria for biodegradation set by international guidelines and standards.

— A substance or material can only be returned into the biosphere in compliance with regulations and if all precautions have been taken to avoid negative effects to the environment. Depending on context, prior chemical analyses and an environmental risk assessment are appropriate.

Renewable recirculation excludes discharges to land, water or air that threaten the environment or human health.

Examples of recirculation are as follows:

— New food products: Use by-products as ingredients for food products for human consumption (e.g. beer made out of surplus bread).

— Inputs for agriculture: Examples include organic fertilisers, animal feed and fish feed.

The calculation of the circularity indicator is performed by applying Formula (A.7):

$$P_{\mathrm{RENO}(X)} = \left(\frac{m_{\mathrm{RENO}(X)}}{m_{\mathrm{TO}(X)}} \right) \cdot 100 \tag{A.7}$$

where

$P_{\mathrm{RENO}(X)}$ is the per cent actual recirculation of outflow (X) in the biological cycle, in %;

$m_{\mathrm{RENO}(X)}$ is the mass of outflow (X) that is renewable recirculation, in kg or other mass unit;

$m_{\mathrm{TO}(X)}$ is the total mass of outflow (X), in kg or other mass unit.

A.4 Energy

A.4.1 Introduction to energy circularity indicators

The energy circularity indicators represent the fraction of energy used by the system in focus that is renewable energy. Energy recovered (e.g. from hot water) from another organization and energy derived from co-products can also be relevant for consideration and are captured in an additional indicator in Annex B (e.g. see B.4.2).

Energies relevant to a given process or system can be subdivided into:

— energies derived from renewable energy resources;

— energies derived from virgin non-renewable resources (e.g. fossil fuels) or renewable materials that do not meet requirements of A.2.4;

— energies derived from residual, non-renewable sources.

A.4.2 Average per cent of energy consumed that is renewable energy

The "average per cent of energy consumed that is renewable energy" represents the fraction of consumed energy that qualifies as renewable energy. The circularity indicator takes into consideration both energy inflows and energy outflows to calculate the fraction of net total energy consumed that is renewable energy. It includes all of the used energy inputs of the system in focus (e.g. for manufacturing a product or for powering a city), including consumed energy for by-products or resource management.

Acknowledging non-renewable inputs can be required to account for the capture, transmission and conversion of energy from a renewable source to electricity. These inputs to renewable energy sources should be monitored and documented to measure and assess circularity.

A common suitable measurement unit (e.g. MJ, kWh) shall be selected for the quantification of all relevant energies (e.g. thermal, electrical) that are involved in the measurement.

Renewable energy outflow is addressing, for example, processes (e.g. utilities) with on-site energy production supplying energy to a grid or outside system thus showing renewable energy outflow.

The calculation of the circularity indicator is performed by applying Formula (A.8):

$$P_{\mathrm{ECONRE}(X)} = \left[\frac{\left(E_{\mathrm{IRENE}(X)} - E_{\mathrm{ORENE}(X)} \right)}{E_{\mathrm{ITE}(X)} - E_{\mathrm{OTE}(X)}} \right] \cdot 100 \qquad \text{(A.8)}$$

where

$P_{\mathrm{ECONRE}(X)}$ is the average energy (X) consumed that is renewable energy, in %;

$E_{\mathrm{IRENE}(X)}$ is the renewable energy (X) inflow, in MJ (or in kWh);

$E_{\mathrm{ORENE}(X)}$ is the renewable energy (X) outflow, in MJ (or in kWh);

$E_{\mathrm{ITE}(X)}$ is the total energy (X) inflow, in MJ (or in kWh);

$E_{\mathrm{OTE}(X)}$ is the total energy (X) outflow, in MJ (or in kWh).

A.5 Water circularity indicators

A.5.1 Introduction to water circularity indicators

Water is an important resource and a focus of the circular economy. The circularity indicators for water consider water inflows, water outflows, internal water reuse and water quality.

Water circularity is considered local in nature, and important to local ecosystems, which depend on sufficient water quantities and qualities to thrive. This determines water availability and quality for all water users in the area. Several key actions are required to maintain the circularity of water, these include:

a) water reduction: minimizing water consumption and managing waste of water;

b) water reuse: applies to water not requiring additional treatment or refurbishing for repeated use within a facility;

c) water recycling on-site: where additional treatment and refurbishing are needed within facility processes and/or on-property for further use or discharge;

d) water recycling off-site: where additional treatment and refurbishing for beneficial use off-site as an alternative to discharge as industrial effluent.

The designation of a water inflow or a fraction of an inflow from circular sources should be documented with evidence to demonstrate that the level of circularity content is not overstated. If there is ambiguity or uncertainty about which type of content is applicable, the user should decide based on the available information and document the rationale. Different types of circular inflow sources should be measured and recorded separately (see Figure A.3).

Information collected in support of a water footprint assessment according to ISO 14046 can be useful in assessing water circularity and calculating water circularity indicators.

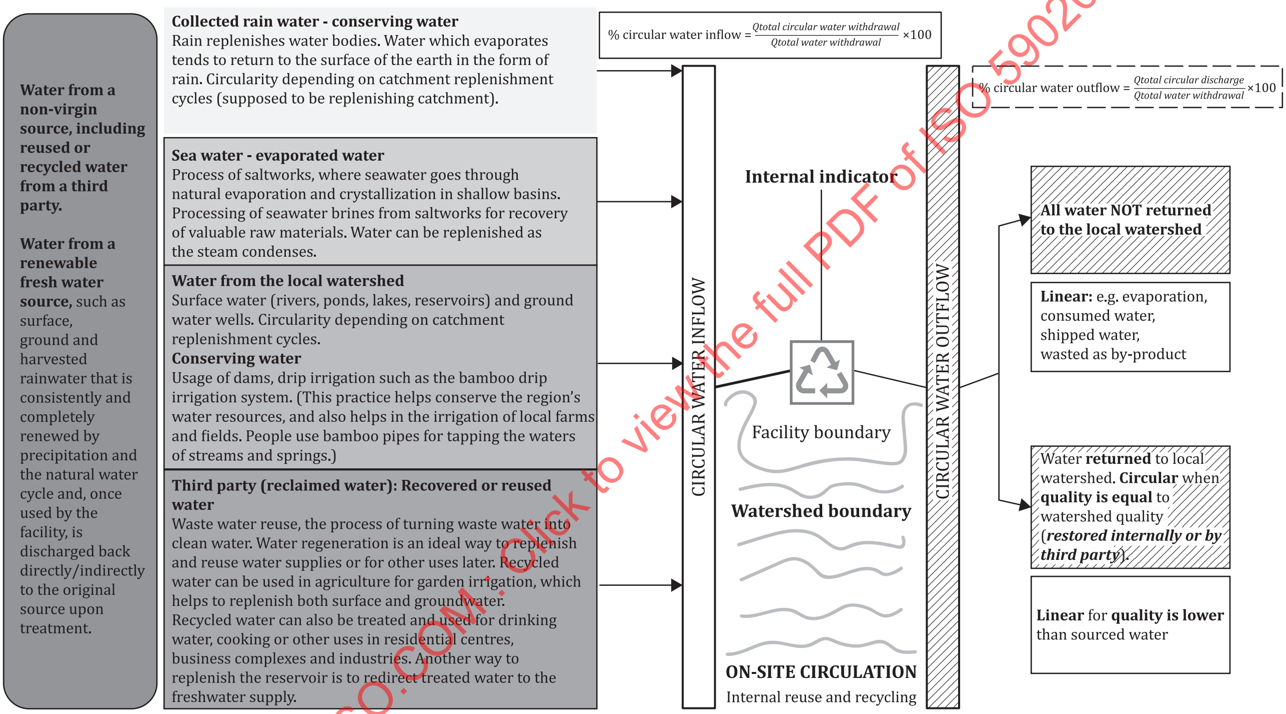


Figure A.3 — Water inflow circular sources and circular water outflow

A.5.2 Per cent water withdrawal from inflow circular sources

This indicator expresses the percentage of annual water demand that is derived from circular sources. A circular water source provides for recirculation of water resources within a process or the hydrologic cycle. Circular inflow sources fulfil all the following criteria:

a) Prior use or natural renewability: Water from a non-virgin source, including reused or recycled water from a third party, water from a renewable freshwater source, such as surface, ground and harvested rainwater that is renewed by precipitation and the natural water cycle, non-freshwater natural sources such as sea or brackish water, and water in raw materials or extracted from a product. Once used by the facility, circular water is ultimately returned to the local watershed following required treatment.

b) A water management plan in place to minimize the impacts to local environments.

Meaningful calculations require proper determination of the boundaries of the system in focus and inflows and outflows of the system in focus. ISO 14046 contains guidelines on how to assess the water footprint.

Many factors related to the sustainable use of water are not taken into consideration in this document but can also need to be assessed: water withdrawal can have an impact on water scarcity, which depends on the location and time where the water is extracted. Climate change can also impact water levels and replenishment rates. Depending on the local conditions, including water quality and water stress, trade-off assessments can be needed to prioritize either water footprint or CO_2emissions.

The calculation of the circularity indicator is performed by applying Formula (A.9):

$$P_{CWW} = \left(\frac{V_{CIW}}{V_{AIW}}\right) \cdot 100 \qquad \text{(A.9)}$$

where

P_{CWW} is the average water withdrawal from circular sources, in %;

V_{CIW} is the volume of water inflow from circular sources, in m^3/year;

V_{AIW} is the volume of water inflow from all sources, in m^3/year.

A.5.3 Per cent water discharged in accordance with quality requirements

This is the percentage by volume, over a given period of time, of water consumed in process and operations that leaves the infrastructure for reuse by another organization or is returned to the water source at the same or better-quality level as that extracted based on the consideration of environmental authorities who set the environmental permit limits. Common water quality parameters include biochemical oxygen demand (BOD), pH and temperature. For information, ISO 22447 details water minimum quality parameters for wastewater discharges, while ISO 14046 contains general water quality guidelines that are appropriate to allow assessment of an ecosystem's ability to thrive.

Losses and releases, such as effluents, spillage or evaporation, that are not returned to the local water source are treated as non-circular outflows. The losses and releases plus water incorporated in products (which does not get returned to the origin at high water quality) plus the water discharged in accordance with circular economy principles should equal the total amount of water withdrawn.

Circular water discharges are water discharges that are consistent with their availability for all environmental, social, agricultural or industrial purposes including supplies to other organizations. They should have appropriate water quality characteristics (including all relevant effluent parameters and temperature).

The calculation of the circularity indicator is performed by applying Formula (A.10):

$$P_{CDW} = \left(\frac{V_{CDW}}{V_{AIW}}\right) \cdot 100 \qquad \text{(A.10)}$$

where

P_{CDW} is the average circular water discharges, in %;

V_{CDW} is the volume of circular water discharges, in m^3/year;

V_{AIW} is the volume of water inflow from all sources, in m^3/year.

A.5.4 Ratio (on-site or internal) water reuse or recirculation

The "ratio (on-site or internal) water reuse or recirculation" indicator measures the circularity of water within a facility for the reporting period. It compares the total water use from all processes and operations within the facility to the amount of water withdrawn from all sources. The ratio of the quantity of on-site circulation of water to the quantity of total water withdrawn will exceed 1,0 when water is reused or recirculated within the facility since the quantity of required water by the facility surpasses the amount of water that is withdrawn.

EXAMPLE Condensate water in cooling towers is being constantly reused for cooling rather than being discharged and additional water withdrawn from a source is only used to compensate for losses and releases.

The calculation of the circularity indicator is performed by applying Formula (A.11):

$$R_{\mathrm{WRR}} = \frac{V_{\mathrm{TWU}}}{V_{\mathrm{TWW}}} \quad \text{(A.11)}$$

where

R_{WRR} is the ratio (on-site or internal) of water reuse or recirculation; it is dimensionless and represents the amount of water recycled or reused within the facility after it has been contained and adequately treated for reuse, as needed;

V_{TWU} is the total water consumed in all processes and operations within the facility, in m^3 per year; typically, the water used in a process or operation is the amount of water entering the process;

V_{TWW} is the total water withdrawn from all external sources, in m^3 per year; an external source is one from a local supply and not provided by internal processes or operations.

A.6 Economic

A.6.1 Introduction to economic circularity indicators

The application of economic-related circularity indicators is of high importance for an organization to provide transparency and demonstrate that circular strategies and actions are economically feasible. The measurement and evaluation of economic viability can be based on the way economic value can be created and captured and how the realization of related actions affects such value.

Specific and well-qualified circularity indicators for the circular economy (as opposed to extensions of linear economy) are less available. Most organizations use simple established linear economy indicators to measure profits, costs, value, revenue, economic viability, etc. Organizations, particularly at the product system level, can use an LCC approach which assigns costs to each of the constituent operations, processes and life cycle phases within a defined system. Organizations can consider both costs and benefits including the following:

— Costs: For example, transformation cost for innovation; manufacturing-and-distribution-related infrastructure; human resources; awareness building; capacity building for processes and collaboration; strategy-induced investments to scale-up circular measures and approaches, product-lifetime-related additional quality and material costs.

— Benefits: For example, expected or realized economic benefits from circular strategies; increased turnover (increasing the scale of circular measures and approaches); earnings per unit or overall; return on investments; resource efficiency; product-lifetime extensions; changes in total cost of product ownership (lifetime), market share (by addressing specific and changing customer needs); incentives and tax reductions.

NOTE A description of how costs and benefits can be calculated is described in ISO 14007. This document only describes the circularity indicators that have been developed specifically for, or are useful, as a measurement of economic value, costs and benefits directly associated with circularity. Other measures derived from the linear economy that can be used to indicate improved economic circularity are described in Annex B, and include net value added, value per mass, resource productivity and genuine progress indicator.

Some indicators in Clause A.6 (and Clause B.6) can include monetary units in their calculation. The impact of inflation and other currency valuation factors should be considered when making comparisons.

A.6.2 Material productivity

The "material productivity" (MP) indicator (sometimes described as "circular material productivity", CMP) is the ratio of an organization's (or a product's) revenue to total linear (non-circular) resource inflows. The MP indicator shows the ratio of revenue to resource intensity and indicates the company's effectiveness in generating income while decreasing linear resource consumption. An increase in this indicator demonstrates financial growth while reducing (linear) resource dependence.

Organizations can calculate circular (material) productivity by dividing revenues generated by the mass of linear inflow. The indicator can be made more specific by considering different resource types (plastic, metal, ceramic, etc.). The outcome produces a value that companies can monitor over time.

The distinction of linear and circular inflows should be carefully considered. Subclause A.2.1 describes what is considered linear among resource inflows in the calculation of the resource inflows circularity indicators, which should be applied consistently in the calculation of the circular (material) productivity.

The calculation of the circularity indicator is performed by applying Formula (A.12):

$$R_{MP} = \frac{C}{D} \quad \text{(A.12)}$$

where

R_{MP} is the MP ratio, in monetary units per kg (e.g. $/kg, €/kg);

C is the total revenue generated in monetary units (e.g. $, €);

D is the total mass of all linear resource inflows, in kg or other mass unit.

A.6.3 Resource intensity index

The "resource intensity index" (RII) indicator (also known as the "decoupling index") is a well-used and demonstrated indicator for higher system levels. It is the ratio of the change rate of resource consumption to the change rate of gross domestic product (GDP) over a period of time. It provides a quantitative measure of economic growth versus total resource use. While mainly used at the regional system level, it can be used for products or organizations following suitable modification by using, for example, the revenue generated. An organization applying this indicator can need to consider the contributions from outside the system in focus such as the source of raw materials and other elements in the value chain.

NOTE Alternately, for the regional system level, domestic material consumption (DMC) to raw material consumption (RMC) can be used.

The calculation of the circularity indicator is performed by applying Formula (A.13):

$$I_{RII} = \frac{(E)}{F} \quad \text{(A.13)}$$

where

I_{RII} is the RII, expressed as a ratio;

E is the rate of variation of resource inflow consumption (mass) per unit time; it is dimensionless;

F is the rate of variation of GDP per unit time; it is dimensionless.

Annex B
(informative)

Additional indicators

B.1 Overview

The core circularity indicators in Annex A can be supplemented by additional indicators, examples of which are provided in this annex. These can be emerging circularity indicators not yet established, indicators that measure specific circularity aspects that are important to the goal and scope of a circularity measurement (but not adequately addressed by the core circularity indicators), or indicators that are not directly focused on circularity but can be useful in qualifying or quantifying the transition from the linear economy.

Some of the indicators in this annex are indicative of a measurement aspect and additional specifications or reference standards can be required to measure the relevant information and to calculate the indicator.

Additional indicators or considerations are provided in Table B.1 for the resource inflow, resource outflow, energy, water and economic categories.

Table B.1 — Additional indicators

Indicator category	Indicator	Description
B.2 Additional resource inflow indicators	No indicators specified	Guidance provided on resource efficiency and reducing inflows
B.3 Additional resource outflow indicators	B.3.2 Per cent designed reusability rate of the outflow	Reusability based on design
	B.3.3 Per cent designed recyclability rate of the outflow	Recyclability based on design
B.4 Additional energy indicators	B.4.2 Per cent energy recovered from residual, non-renewable and non-recoverable resource outflows	Per cent energy recovered from residual, non-renewable and non-recoverable resource outflows
	B.4.3 Energy intensity	The amount of energy used to produce a given level of output or activity
B.5 Additional water indicators	B.5.2 Nutrient extraction from discharged water	Extraction of nutrients from water before discharge
	B.5.3 Water intensity	The amount of water used to produce a given level of output or activity
B.6 Additional economic indicators	B.6.3 Net value added	Value of a product minus negative economic factor costs
	B.6.4 Value per mass	Value per unit mass of resource
	B.6.5 Resource productivity	Ratio of GDP and DMC or RMC
	B.6.6 Genuine process indicator	Measures GDP after removing negative impact costs

Indicators that measure or assess other aspects or impacts relevant to circularity performance and the system in focus can also be used or can be developed in the future. Topics that can be considered are:

— resource consumption (e.g. standards to calculate consumption footprints);

— intensity of resource use (e.g. indicators of kg input per kg output);

— emerging renewable resources, processes and products can require additional indicators or assessment methods;

— changes in circularity performance over time (see guidance in Clauses 6 to 8 to ensure consistency and comparability).

These and other topics can leverage complementary methods and are further described in Clause 8 and Annex C.

B.2 Additional resource inflow indicators

B.2.1 Considerations for additional resource inflow indicators

There are no additional indicators for resource inflows currently specified. Indicators that measure or assess consumption of resources or intensity of resource use can be considered.

Reducing the use of resource inflows in absolute terms contributes to narrowing resource flows. It is particularly important to minimize the amount of virgin resource extraction and the use of non-renewable resources. The resource inflow circularity indicators given in A.2.1 to A.2.4 can be used to calculate the total mass of input materials. Organizations can use these data to monitor changes in the resource inflows over time by setting a reference point in time and collecting data periodically. Trends in resource use can only be reliably monitored if the periodic data are calculated under the same boundary conditions as the baseline.

B.3 Additional resource outflow indicators

B.3.1 Introduction to additional resource outflow indicators

Additional resource outflow indicators can be used to measure design aspects and other considerations in the circularity of resource outflows. This can include design for reuse of products or components of the product once it leaves the system in focus (i.e. reusability) or design for recycling (i.e. recyclability).

Substances of concern in material outflow can be relevant for specifying additional indicators. For example, safe material choices are a necessary condition for circularity. When systems thinking has been applied at the design stage, the resulting safe material choices become measurable in the material outflow. Avoiding any substances of concern is an important step in improving the circular characteristics of products, as this will reduce the amount of waste to be treated as hazardous waste instead of being recirculated in the economic system at the end of use.

A consideration can be the percentage of outflow that does not contain any substances of concern above the relevant thresholds (e.g. supplier declarations).

B.3.2 Per cent designed reusability rate of the outflow

This indicator measures the share of the resource outflow (e.g. which can be entire products or components) that is reusable, as intended by the manufacturer. A resource outflow is reusable if it can be used during multiple cycles and the design intent can be demonstrated by physical characteristics such as quality, repairability, dismantlability (to obtain parts/components) or circular strategies to maintain the functionality of a product such as repair and upgrade services or reuse systems. Also, organizations should communicate the reusability feature to the user in order to increase the likelihood that the part, component or product will be reused in the future.

A user can reuse a product multiple times within the expected product lifetime but at the end of use, professional organizations (e.g. operators specialized in preparation for reuse or remanufacturing) are often necessary to facilitate extending the life of the product through reuse.

The calculation of the circularity indicator is performed by applying Formula (B.1):

$$P_{\mathrm{DFRM}} = \left(\frac{m_{\mathrm{DFRO}(X)}}{m_{\mathrm{TO}(X)}} \right) \cdot 100 \tag{B.1}$$

where

P_{DFRM} is the per cent of outflow mass that is designed for reuse of components and products, in %;

$m_{\text{DFRO}(X)}$ is the mass of components or products in the outflow (X) that are designed for reuse, in kg or other mass unit;

$m_{\text{TO}(X)}$ is the total mass of outflow (X) in kg or other mass unit.

B.3.3 Per cent designed recyclability rate of the outflow (X)

During the design phase, it is important to account for how components and materials can be recycled when the product reaches its end of use. This includes the potential of the product components and materials to be disassembled, separated into material streams and ultimately processed into recycled material. It should be noted that the recyclability can be very different from per cent actual recycled material derived from an outflow (see A.3.4) which takes into account the actual recovery rates and recycling operations associated with the product in the applicable geographies.

The “per cent designed recyclability rate of the outflow (X)” circularity indicator represents the share of the resource outflow that is designed and manufactured such that it be can be processed into recycled material. It is based on the design for recycling as intended by the manufacturer. This indicator can provide useful insight to help an organization improve the recycling of its products. However, it is not a substitute for the per cent actual recycled material derived from an outflow (see A.3.4).

The design intent can be demonstrated by, for example, the use of materials that are fully recyclable with existing recycling schemes, selection of fewer material types and increased material homogeneity, ability to dismantle the product or the suitability of the product parts and materials for recycling into high quality materials and the implementation of adequate guidelines for design for recycling for the product type. It should be demonstrated and reported that the product and used materials can be recycled by an existing recycling scheme and that use phase does not significantly change the recyclability (e.g. contamination preventing recycling).

For some sectors or product categories, standards or norms have been created with end-of-life treatment scenarios or rules for calculating recyclability rates. These should be used when available. For energy-related products, EN 45555 can be relevant in determining the recyclability of an outflow; it specifies requirements and guidance for developing an end-of-life treatment scenario and calculating the recyclability rate. Also, IEC/TR 62635 reports on guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment.

The calculation of the circularity indicator is performed by applying Formula (B.2):

$$P_{\text{DRMO}(X)} = \left(\frac{m_{\text{DRMO}(X)}}{m_{\text{TO}(X)}} \right) \cdot 100 \tag{B.2}$$

where

$P_{\text{DRMO}(X)}$ is the per cent of mass that is designed for recycling in the outflow (X), in %;

$m_{\text{DRMO}(X)}$ is the mass of material that is designed for recycling in the outflow (X), in kg or other mass unit;

$m_{\text{TO}(X)}$ is the total mass of outflow (X) in kg or other mass unit.

B.4 Additional energy indicators

B.4.1 Introduction to additional energy indicators

Two additional energy-related indicators are provided in B.4.2 and B.4.3. These indicators provide useful information in the transition to a circular economy. The energy intensity indicator in B.4.3 is applicable to both the linear economy and the circular economy.

B.4.2 Per cent energy recovered from residual, non-renewable and non-recoverable resource outflows

Non-recoverable resources in outflow are resources that cannot be recovered and used again after they have been processed or used due to technological, economic, environmental, social or regulatory infeasibility. Instead of being destined for disposal following their use cycles, residual, non-renewable resources of negligible or negative material value, which is considered as non-recoverable, can be used for the generation or recovery of energy. The non-renewable resources that can be used for energy recovery include, for example, waste (via processes such as bio-gas production, pyrolysis, gasification, incineration with energy recovery, etc.), heated water from chemical plants and water used for washing (e.g. by condensation or heat exchange).

NOTE Negative material value can be a result of resources with detrimental environmental or ecological impacts. For example, material resources of very low or negative values can include unwanted or contaminated products.

This indicator represents the per cent energy recovered from residual, non-renewable resource outflows divided by the total energy inflow. The total energy inflow can be composed of the following:

— energies derived from renewable energy resources;

— energies derived from virgin non-renewable resources (e.g. fossil fuels) or renewable materials that do not meet requirements of A.2.4;

— energies derived from residual, non-renewable resources.

The calculation of the circularity indicator is performed by applying Formula (B.3):

$$P_{\mathrm{RNRENE}} = \frac{(100 \cdot E_{\mathrm{INRENE}})}{E_{\mathrm{TIE}}} \quad \text{(B.3)}$$

where

P_{RNRENE} is the energy recovered from residual, non-renewable and non-recoverable resource outflows, in %;

E_{INRENE} is the inflow energy derived from residual, non-renewable and non-recoverable resources, in MJ (or in kWh);

E_{TIE} is the total inflow energy in in MJ (or in kWh);

B.4.3 Energy intensity

Energy intensity is defined as the amount of energy used to produce a given level of output or activity. It includes all energy inputs of the processes of manufacturing a product and/or delivering a service, such as consumed energy for by-products or resource management. Minimizing the usage of energy to provide a product or service results in optimized energy intensity.

The methodology to calculate the energy intensity varies depending on the type of product or production unit. Therefore, product sector standards can be used to determine the industry average and to measure the industry average energy intensity, leading to a comparative indicator relative to the market average.

The calculation of the circularity indicator is performed by applying Formula (B.4):

$$I_{EI} = \frac{E_{TIE}}{n_{PU}} \quad \text{(B.4)}$$

where

I_{EI} is the energy intensity calculated during the reference time period, in MJ (or in kWh);

E_{TIE} is the total inflow energy during the reference time period, in MJ (or in kWh);

n_{PU} is the number of unit products, n, produced during the reference time period.

NOTE The calculated energy intensity can be compared to the industry average to assess the performance of a process or solution. Energy intensity performance relative to industry average can be calculated as a ratio between the energy intensity measured for the system in focus and the industry average energy intensity.

B.5 Additional water indicators

B.5.1 Introduction to additional resource outflow indicators

An additional water indicator that considers the level of nutrient extraction from used water and effective recirculation is provided.

B.5.2 Nutrient extraction from discharged water

B.5.2.1 General

Any surplus nutrients and related materials (e.g. above levels that would lead to eutrophication) that have been introduced to the water flow within the system in focus should be removed from the water during its recirculation or at the point of discharge. The extracted nutrients can be valuable resources and can be evaluated for further use. By extraction, they can be maintained within the wider economic system or safely returned to the biosphere, as a circular way of mitigating potential issues associated with the surplus.

Nutrients include, for example, nitrate, phosphorous as phosphate, metals (e.g. Ca, Fe, Na, K), carbohydrates (e.g. lipids, fats, sugars), proteins and vitamins.

Within this indicator, two contributions should be considered:

— the amount of water that has been discharged after the extraction of nutrients;

— the percentage of materials (relative to those originally present) extracted.

The information to be measured is:

— the amount of water discharged;

— the amount of treated (i.e. nutrients extracted) water discharged;

— the nutrients in water, i.e. the total amount of materials present in the water discharge prior to extraction;

— the total amount of nutrients extracted.

The indicator can be calculated by alternative Methods A (see B.5.2.2) and B (see B.5.2.3). Either method can be used to indicate the effectiveness of extraction but applying both methods provides a more complete description.

B.5.2.2 Indicator Method A

The percentage of water from which all surplus nutrient and related materials have been extracted, before discharge of the water from the system in focus, with respect to the total water discharged is calculated by applying Formula (B.5):

$$W_{E} = \frac{(100 \cdot W_{DTRD})}{W_{DTOT}} \tag{B.5}$$

where

W_{E} is the per cent of nutrient extracted water discharged;

W_{DTRD} is the volume of water discharged subjected to extraction, in m^3 or suitable volume unit;

W_{DTOT} is the total volume of water discharged, in m^3 or suitable volume unit.

B.5.2.3 Indicator Method B

The percentage of the mass of extracted surplus materials (that have been introduced to the water within the system in focus) which have been safely returned to the economy or environment through recycling, reuse or nutrient recirculation, with respect to the original mass of materials prior to extraction is calculated by applying Formula (B.6):

$$P_{ESMAT} = \frac{(100 \cdot m_{MATEXT})}{m_{MATPTE}} \tag{B.6}$$

where

P_{ESMAT} is the percentage of extracted surplus materials;

m_{MATEXT} is the mass of materials extracted, in kg or other mass unit;

m_{MATPTE} is the original mass of materials prior to extraction, in kg or other mass unit.

B.5.3 Water intensity

Water intensity is defined as the amount of water used to produce a given level of output or activity. It includes all water use/consumption by the manufacturing process, operations to deliver a service and other organizational activities. Reducing the total water use/consumption needed to deliver a product or service results in improved water intensity. The exact methodology to calculate the water intensity varies depending on the type of product or production unit. Specific-sector standards on water footprint assessment (e.g. ISO 14046) can be used to determine/measure the water intensity of the system in focus (as well as the industry average to enable comparison).

In a circular economy, the objective is to reduce or minimize (virgin) resource use and extraction, which also includes water. Therefore, water intensity is a useful indicator to assess the efficiency of water consumption.

The calculation of the indicator is performed by applying Formula (B.7):

$$I_{WI} = \frac{E_{TIW}}{n_{PU}} \tag{B.7}$$

where

I_{WI} is the water intensity calculated during the reference time period, in l;

E_{TIW} is the total inflow (withdrawal/use/consumption) of water during the reference time period, in l;

n_{PU} is the number of unit products (output or activity), n, produced during the reference time period.

B.6 Additional economic indicators

B.6.1 Introduction to economic indicators

There are several economic indicators that are not specifically developed to measure circularity but can be used to assist with the transition that is needed from a linear economy to a circular economy.

B.6.2 Revenue share related to circularity

There is currently no widely accepted common definition of a circular product that is robust, reliable and verifiable. However, measuring the share of an organization's total sales revenue of products and solutions that contribute to the circular economy is being used in practice. It is usually expressed as percentage of sales revenue generated per year through the sales of the so-called "circular products". Increases in this indicator represent an improved circularity performance of the organization's efforts to contribute to a circular economy.

This document does not provide such an economic circularity indicator because of the lack of consensus on what constitutes a circular product and how the circularity can be calculated in a very clear manner. This increases the risk of misleading information.

To measure the circularity performance of a product, the organization should apply the mandatory resource inflow and resource outflow circularity indicators of Clauses A.2 and A.3.

B.6.3 Net value added

The net value added (NVA) indicator measures the value of a product minus negative economic factor costs. Factor costs include indirect taxes, depreciation, increasing rent, etc. However, this can be modified to include negative effects of transition to circular strategies by including capital costs, increased resource costs and increased labour costs. While NVA is used as a linear economy tool, it does allow organizations to estimate the advantages and disadvantages of implementing a circular value creation model.

The information required to calculate this indicator is sales, stock, capital expenditure, costs associated with workers, training and productivity changes, as well as economic factors such as depreciation, monetary exchange, indirect takes, etc.

The calculation of the circularity indicator is performed by applying Formula (B.8):

$$I_{NVA} = G + H - J \quad \text{(B.8)}$$

where

I_{NVA} is the NVA indicator, in monetary units (e.g. $, €);

G is the total revenue generated by the use of circular resources, in monetary units (e.g. $, €);

H is the stock change, in monetary units (e.g. $, €);

J is the sum of all negative economic factors, in monetary units (e.g. $, €).

B.6.4 Value per mass

Value per unit mass of resource provides estimation of the efficiency of resource use. While increasing value per mass shows increasing circularity (whether due to recycling, reuse, remanufacturing, etc. or increased resource efficiency), comparisons are only valid within a specified system or closely related systems.

The information to be measured is sales, stock and mass of resource(s) input.

The calculation of the circularity indicator is performed by applying Formula (B.9):

$$I_{\text{VPUM}} = \frac{K}{L} \tag{B.9}$$

where

I_{VPUM}	is the value per unit mass (VPUM) of resource(s) input, in monetary units per kg (e.g. \$/kg, €/kg);
K	is the product revenue value, in monetary units (e.g. \$, €);
L	is the total mass of resource(s) used, in kg.

B.6.5 Resource productivity

Resource productivity is similar to value per mass but is extended to the regional system level by use of GDP rather than revenue. It allows a region or country (or organization following suitable modification) to track progress towards a circular model. Its weakness is that the resource productivity can change depending on the type of products manufactured or used and can change as the economy of a region, country or organization change.

GDP is not always the ideal measure of a region's economic activity as it does not include non-financial transactions or imports, and other economic indicators may be considered.

The information to be measured is GDP (or DMC or RMC depending on the system level).

The calculation of the circularity indicator is performed by applying Formula (B.10):

$$I_{\text{RP}} = \frac{M}{N} \tag{B.10}$$

where

I_{GPI}	is the genuine progress indicator (GPI), in monetary units (e.g. \$, €);
M	is the GDP, in monetary units (e.g. \$, €) (or DMC or RMC);
N	is the sum of negative impact costs, in monetary units (e.g. \$, €).

B.6.6 Genuine progress indicator

The GPI is suited to the higher system levels. It is a correction to GDP accounting for negative impacts. It is often used as an alternative to GDP and considers negative effects related to economic activity, such as environmental impacts among others. Although not strictly defined for circularity, it is highly useful as the GPI reflects the positive and negative results of economic growth. It can be modified by consideration of factors such as DMC, RMC, recycling rates, flows to land fill and incineration, recovery costs, etc.

The information to be measured is GDP (or DMC or RMC or recycling rates or landfill/incineration rates depending on the system level).

The calculation of the circularity indicator is performed by applying Formula (B.11):

$$I_{GPI} = M - N \tag{B.11}$$

where

I_{GPI}	is the GPI, in monetary units (e.g. \$, €);
M	is the GDP, in monetary units (e.g. \$, €) (or DMC or RMC or recycling rates or landfill/incineration rates);
N	is the sum of negative impact costs, in monetary units (e.g. \$, €).

Annex C
(informative)

Complementary methods

C.1 General

In measuring and assessing the circularity performance, this document is intended to avoid overlap with and duplication of existing methods such as LCA.

MFA or RFA is already an integrated part of the measurement and assessment process in this document.

With regard to the objective of contributing to sustainable development, it is recommended to apply the UN Agenda 2030[54], to assess the impact to social, economic and environmental issues.

This annex provides a non-exhaustive overview of these type of complementary methods.

C.2 Complementary methods and criteria of selection

C.2.1 General

Complementary methods can be applied to measure and assess social, environmental and economic impacts and values that are caused by the actions to achieve circular goals. An organization is free to choose complementary methods that fit best to its activities and context. Complementary methods can be used to link circular actions to other sustainability initiatives or programmes relevant at organizational, product/solution, industry sector, regional or world level (e.g. the SDGs, social development programmes, carbon footprint measurement and sustainable procurement).

The criteria of selection are given in C.2.2 to C.2.4.

The different complementary methods evaluate different aspects of a circular action. To make the choice of a particular methodology globally consistent, the complementary methods are grouped for selection based on their standardization and type of promoting organism. This categorization is useful in the context of the circular economy since the decisions made in this framework have the potential to affect different productive sectors and value chains and to also generate social, environmental and economic impacts around the world. In this context, complementary methods can be selected between tools of wide dissemination and use, recognized and validated worldwide.

Clauses C.3 and C.4 provide a list of complementary methods standards. When possible, a standard from Clause C.3 is preferable. In the absence of the appropriate standardized methodology from this first group to evaluate some required aspect (e.g. the social impact of a production decision or choice of materials), a standard from Clause C.4 and beyond can be selected.

To determine which complementary methods are relevant, the following options can be considered:

— the ISO, or where available, IEC standardized methods;

— methods promoted and standardized by international organizations in which most of the world's countries participate, such as the UN, the International Labour Organization (ILO) and the World Trade Organization (WTO);

— methods promoted by regional organizations or representative of groups of countries, such as OECD, APEC, OAS, European Commission, Mercosur (such as Economy-Wide Material Flow Accounts from OECD);

— methods promoted and used by industrial associations and international NGOs (e.g. the methods recommended by the World Business Council for Sustainable Development (WBCSD), the Electrical and Electronics Industry Association, Cement Association, ICMM and the Ellen McArthur Foundation).

C.2.2 Consistent with the system level

The system level of the system in focus (from regional, interorganizational or organizational to product level) should be taken into consideration as not all potential complementary methods can be adapted or adequately used to assess different aspects of a circular action.

EXAMPLE Economic-wide material flow analysis (EW-MFA) can be adequately used for the regional and perhaps interorganizational levels but can be a subject of significant uncertainty at the organizational or product level.

C.2.3 Consistent with the system boundary

Time frame and spatial and geographical scales can play an important role in choosing a specific complementary method.

EXAMPLE The dilution or stock of material into the technostructure can imply the use of MFA instead of traditional mass balance to assess material availability.

C.2.4 Expert capabilities

Ensure that at least one team member has enough knowledge and experience with different complementary methods. Refer to ISO/TS 14071.

C.3 International Standards for measurement and assessment

The following non-exhaustive list of International Standards can be applied for measurement and assessment:

— ISO 14001 specifies the requirements for an environmental management system that an organization can use to enhance its environmental performance. It is intended for use by an organization seeking to manage its environmental responsibilities in a systematic manner that contributes to the environmental pillar of sustainability. It helps an organization to achieve the intended outcomes of its environmental management system, which provide benefits for the environment, the organization itself and interested parties. It is applicable to any organization, regardless of size, type and nature, and applies to the environmental aspects of its activities, products and services that the organization determines it can either control or influence considering a life cycle perspective.

— ISO 14051 provides a general framework for material flow cost accounting (MFCA). Under MFCA, the flows and stocks of materials within an organization are traced and quantified in physical units (e.g. mass, volume) and the costs associated with those material flows are also evaluated. The resulting information can act as a motivator for organizations and managers to seek opportunities to simultaneously generate financial benefits and reduce adverse environmental impacts. MFCA is applicable to any organization that uses materials and energy, regardless of their products, services, size, structure, location, and existing management and accounting systems. Under a circular economy framework, MFCA can provide valuable information for resource efficiency as it can be used to improve eco-efficiency analysis as well as in strategic decision-making processes within organizations.

— ISO/TS 14071 provides requirements and guidelines for conducting a critical review of any type of LCA study and the competencies required for the review. It provides: details of a critical review process, including clarification with regard to ISO 14044; guidelines to deliver the required critical review process, linked to the goal of the LCA and its intended use; content and deliverables of the critical review process; guidelines to improve the consistency, transparency, efficiency and credibility of the critical review process; the required competencies for the reviewer(s) (internal, external and panel member); the required competencies to be represented by the panel as a whole. It does not cover the applications of LCA.

— ISO 14040 describes the principles and framework for LCA including: definition of the goal and scope of the LCA, the LCI analysis phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements.

— ISO 14044 specifies requirements and provides guidelines for LCA including: definition of the goal and scope of the LCA, the LCI analysis phase, the LCIA phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements.

  "LCA can provide technical support to [circular economy] decision-makers, to assess trade-offs of impacts on a variety of environmental impact indicators, such as water use, energy, climate change, and raw materials. LCA can also be applied to identify the most promising [circular economy] actions and options for improving the environmental performance of society's consumption and production patterns. For example, LCA provides a correction to economic analyses based on current taxation regimes, where labour is taxed more than material resources" (Life Cycle Initiative 2020[50]).

— ISO 14067 specifies principles, requirements and guidelines for the quantification and reporting of the carbon footprint of a product (CFP), in a manner consistent with International Standards on LCA (see ISO 14040 and ISO 14044).

— ISO 14046 specifies principles, requirements and guidelines related to water footprint assessment of products, processes and organizations based on LCA. It provides principles, requirements and guidelines for conducting and reporting a water footprint assessment as a stand-alone assessment, or as part of a more comprehensive environmental assessment. Only air and soil releases that impact water quality are included in the assessment, and not all air and soil releases are included. The result of a water footprint assessment is a single numeric value or a profile of impact indicator results.

— ISO 14045 describes the principles, requirements and guidelines for eco-efficiency assessment for product systems. Requirements, recommendations and guidelines for specific choices of categories of environmental impact and values are not included. The intended application of the eco-efficiency assessment is considered during the goal and scope definition phase, but the actual use of the results is outside the scope of ISO 14045.

  EXAMPLE Improving the eco-efficiency of the circular economy system in mining areas can be the most effective way to reduce the greenhouse effect and achieve sustainable development.

— ISO 15686-5 provides requirements and guidelines for performing LCC on buildings and constructed assets, service-life planning. LCC as an economic assessment considering all agreed projected significant and relevant cost flows over a period of analysis expressed in monetary value. The projected costs are those needed to achieve defined levels of performance, including reliability, safety and availability.

— ISO/IEC 17029 includes requirements and guidelines how to set up verification programmes. It can be used for internal (e.g. first party), collaborative (e.g. second party) as well as independent (e.g. third party).

— ISO 20915 specifies guidelines and requirements for conducting LCI studies of steel products. When considering the circularity of steel products, it is recommended to refer to the evaluation methods for recycling in this document.

C.4 International Standards with guidance methods

— ISO 14025 establishes the principles and specifies the procedures for developing Type III environmental declaration programmes and Type III environmental declarations. It specifically establishes the use of the ISO 14040 family of standards in the development of Type III environmental declaration programmes and Type III environmental declarations. It establishes principles for the use of environmental information, in addition to those given in ISO 14020. Type III environmental declarations are primarily intended for use in business-to-business communication, but their use in business-to-consumer communication under certain conditions is not precluded. It Can be used to engage suppliers in sustainable consumption and production schemes in order to take the best decisions in a circular economy programme. It can also be used to communicate in a certified and comparable way (using EPD) the environmental performance of inputs of materials and other supplies.

— ISO/TS 14027 provides principles, requirements and guidelines for developing, reviewing, registering and updating PCR within a Type III environmental declaration or footprint communication programme based on LCA according to ISO 14040 and ISO 14044 as well as ISO 14025, ISO 14046 and ISO 14067. It also provides guidance on how to address and integrate additional environmental information, whether or not it is based on LCA in a coherent and scientifically sound manner according to ISO 14025. It can be used for establishing basic principles to develop rules for measuring and assessing circularity according to product or material categories.

— ISO 20245 establishes minimum screening criteria for second-hand goods that are traded, sold, offered for sale, donated or exchanged between countries. It is intended to help protect health, safety and the environment in which second-hand goods interact, when used by consumers. Is applicable to second-hand goods that are shipped across at least one international border, and where the intended end user is a consumer. It does not apply to goods that are remanufactured, rebuilt or refurbished.

— ISO 20400 assists organizations in meeting their sustainability responsibilities in value chains by providing guidance on: sustainable procurement principles, drivers and key considerations such as priority setting, due diligence and avoiding complicity; integrating sustainability into the procurement policy, organizing the procurement function towards sustainability and defining sustainable sourcing strategies; and integrating sustainability into the procurement process. ISO 20400 is based on ISO 26000, and a detailed description of possible procurement actions for the 37 issues of social responsibility is included in an annex.

— ISO 26000 is a social responsibility guidance standard that includes international guidelines and behavioural norms, such as the UN Declaration on Human Rights[53], UN Guiding Principles on Business and Human Rights[54], and ILO Conventions and Recommendations for Labour Rights. ISO 26000 is a practical and integrated instrument to assist organizations in contributing to sustainable development. It is an all-encompassing guidance, with: seven core subjects: environment, human rights, labour practices, consumer issues, organizational governance, fair operating practices and community involvement and development; seven principles, including accountability, transparency and ethical behaviour; interested party identification, dialogue and value chain responsibility (sphere of influence); practical guidance for integrating corporate social responsibility into core activities and value chains.

— ISO 37120 defines and establishes methodologies for a set of indicators to steer and measure the performance of city services and quality of life. It follows the principles set out in ISO 37101 and can be used in conjunction with ISO 37101 and other strategic frameworks. It is applicable to any city, municipality or local government that undertakes to measure its performance in a comparable and verifiable manner, irrespective of size and location.

C.5 Methods promoted by international organizations (such as the UN)

— Social life cycle assessment (S-LCA)[57]: This is a method that can be used to assess the social and sociological aspects of products, their actual and potential positive as well as negative impacts along the life cycle. This looks at the extraction and processing of raw materials, manufacturing, distribution, use, reuse, maintenance, recycling and final disposal. S-LCA makes use of generic and site-specific data, can be quantitative, semiquantitative or qualitative, and complements the environmental LCA and LCC. It can either be applied on its own or in combination with the other techniques. (See the Life Cycle Initiative 2020[50].)

— Life cycle sustainability assessment (LCSA): This refers to the evaluation of all environmental, social and economic negative impacts and benefits in decision-making processes towards more sustainable products throughout their life cycle. The interest in developing methods to better understand and address the impacts of products along their life cycle has been stimulated by a growing global awareness of the importance of protecting the environment; an acknowledgement of the risks of trade-offs between possible impacts associated with products (both manufactured and consumed); and the necessity of taking account of climate change issues and biodiversity from a holistic perspective (UNEP/SETAC Life Cycle initiative, Principles for the application of life cycle sustainability assessment[35]). The LCSA broad approach is especially valuable as a complementary analysis for the circular economy. It can support evaluating and comparing the most promising circular economy actions and options for improving the environmental performance of society's consumption and production patterns. (See the Life Cycle Initiative 2020[50].)

C.6 Methods promoted by regional or specific international organizations

— Economy-wide material flow accounting, particularly the OECD Methodology[49]: It focuses on the material performance of the economy measured at clearly defined "crossover points" at the outer limit of the national economy. A clear common understanding of what constitutes the national economy and how exactly its outer boundary is defined is helpful to EW-MFA compilers. This clear understanding ensures that material flows are accounted for in a standardized way at conceptually consistent "crossover points" or "measurement points" (European Commission 2018[49]). EW-MFA can be used to calculate the environmental rucksack and the material footprint of goods and services, when transferring flows from one economy to another; it also is related to SDG 8.

C.7 Material property specifications and ASTM standards

The applications and use of primary or secondary materials are determined by their properties and these are strictly controlled or regulated in many industrial sectors. The American Society for Testing and Materials (ASTM) provides specific standards for mechanical, physical, chemical, optical and thermal properties for use in, for example, the medical implant (see ASTM F67), construction (see ASTM C926) and food (see ASTM E460) sectors. Such standards are necessary for health and safety across manufacturing and industry, farming, medical, food, chemicals, etc.

Standards can focus on performance (yield strength, ductility, corrosion resistance) through to physical properties such as crystal structure, grain size and phase composition. Organizations which are specified, can host details of properties across material grades and manufacturers related to application and standards.

Through reuse, remanufacture and recycling processes, many critical material properties can change affecting performance and preventing use in a specified application. This is well documented for plastics and alloys. These changing properties can be used to indicate the efficiency of recycling and other processes and can indicate whether materials are being up cycled, recycled or down cycled. Very often material property specifications are used with other complementary techniques to address the benefit of a circular process. ISO provides guidance for the use of secondary materials (e.g. ISO 59014).

— ASTM E3210: A standard practice for the organization that provides infrastructure asset services such as water, transit, security, where interested party input is integral to the planning, performance and assessment of performance. Revenues and outlays are tracked so as to monitor keeping within the means of the organization, but also selecting the revenue sources that have highest equity in terms of wealth distribution.

Annex D
(informative)

Circular economy and the SDGs

D.1 Contributing to sustainable development

A circular economy system should contribute to sustainable development. This means contributing to the SDGs of the UN Agenda 2030[54]. Circular economy activities can have a positive impact on many SDGs.

This annex provides general information on the relationships between circular economy and the SDGs. It also provides more detailed examples on the relationships with SDG targets and indicators.

NOTE Because the UN Agenda 2030 has been developed and agreed for implementation of the SDGs at regional level (e.g. country, region, city), the measurement of SDG targets and indicators is mostly applicable to public organizations and government institutions. However, the UN Agenda 2030 has inspired many private and non-profit organizations to adopt relevant SDGs into their mission and policies.

D.2 General overview between circular economy and SDGs

The circular economy is strongly related to SDG 12 "Responsible consumption and production". Circularity can also have its roots in SDG 9 "Industry, Innovation and Infrastructure" by improving the circularity performance of buildings and infrastructure.

Figure D.1 shows the circular economy with SDG 12 in the centre and possible relationships with other SDGs.

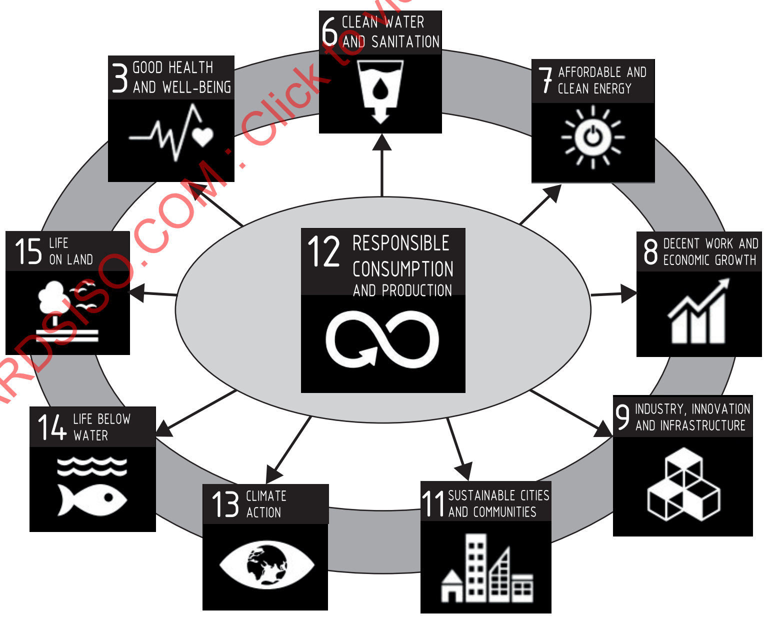


Figure D.1 — Circular economy and relationships with other SDGs

D.3 Direct and indirect relationships between circular economy and SDGs

Circular economy practices can have a clear and direct impact on SDGs and their targets; however, the impact can also be less evident and indirect.

For example, target 12.4 of SDG 12 indicates:

> "12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment".

NOTE In this situation it can be relevant to refer to the target-associated SDG indicators 12.4.1 and 12.4.2, as they provide specific scope, variables, source and type of data, metrics and ways of accounting/calculations that can show or help to make a proper link to circular economy activities:

— Indicator 12.4.1: Number of parties to international multilateral environmental agreements on hazardous waste, and other chemicals that meet their commitments and obligations in transmitting information as required by each relevant agreement.

— Indicator 12.4.2: (a) Hazardous waste generated per capita; and (b) proportion of hazardous waste treated, by type of treatment.

EXAMPLE Circular economy practices and SDGs[52]:

— An important objective to make the circular economy work for SDG 3 and SDG 8 would be to eliminate circular economy practices with negative health impacts on workers in both informal and formal recycling sectors.

— Moreover, what is required is the transfer of recycling technologies and processes that prevent chemical emissions with negative effect on the environment. This would contribute to achieving Target 12.4.

— Current recycling activities carried out by the informal sector will require strong interested party initiatives to implement capacity building, vocational training and technology transfer to turn them into "decent jobs" (Targets 8.3 and 8.5).

— Another example that demonstrates the cross-cutting nature of circular economy practices is SDG 3 (Good health and well-being). Most targets under this goal have no relationship with circular economy practices but implementing circular economy practices under SDG 6 (Water and sanitation) and SDG 7 (Affordable and clean energy) will contribute meaningfully to progress on health and well-being.

— Uptake of circular economy practices related to renewable energy and contribute to achieving energy targets of SDG 7.

D.4 Examples of SDG targets and indicators in relation with circularity indicators

D.4.1 General

When assessing the circularity performance of a specified system, it is valuable to take into consideration the impacts on the SDGs, at a more detailed level of SDG targets and indicators.

Examples on the SDGs mentioned in Figure D.1 are given in D.4.2 to D.4.9.

D.4.2 SDG 3: Good health and well-being

Target 3.9:

— By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.

SDG indicators:

— 3.9.2: Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services).

— 3.9.3: Mortality rate attributed to unintentional poisoning.

Circularity indicator examples, with indirect impact:

— Recycled and cleaned wastewater (cubic meters per day) avoiding pollution of river.

— Reduced hazardous waste to landfill avoiding soil pollution.

Indicator from this document (see A.5.4):

— Ratio (on-site or internal) water reuse or recirculation.

D.4.3 SDG 6: Clean water and sanitation

Target 6.3:

— By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

SDG indicators:

— 6.3.1: Proportion of wastewater safely treated.

— 6.4.1: Change in water-use efficiency over time.

Circularity indictor examples, with direct impact:

— Water use or reduce (m^3) per source (waterboard, rain water, water of river/lake, ground water) in operations.

— Water recycled (m^3) within an organization or between organizations.

— Reduced or prevented hazardous chemicals into water sources.

Indicators from this document (see A.5.3 and A.5.4):

— Per cent water discharged in accordance with quality requirements.

— Ratio (on-site or internal) water reuse or recirculation.

D.4.4 SDG 7: Affordable and clean energy

Target 7.2:

— By 2030, increase substantially the share of renewable energy in the global energy mix.

SDG indicator:

— 7.2.1: Renewable energy share in the total final energy consumption.

Circularity indicator examples, with direct impact:

— Reduction of energy resources (renewable and non-renewable), due to material resource efficiency.

— Energy savings due to refurbishing or remanufacturing of a product portfolio.

Indicators from this document (see A.4.2 and B.4.2):

— Average per cent of energy consumed that is renewable energy.

— Per cent energy recovered from residual, non-renewable and non-recoverable resource outflow.

D.4.5 SDG 8: Decent work and economic growth

Target 8.4:

— Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-

year framework of programmes on sustainable consumption and production, with developed countries taking the lead.

SDG indicators:

— 8.4.1: Material footprint, material footprint per capita and material footprint per GDP.

— 8.4.2: DMC, DMC per capita, and DMC per GDP.

Circularity indicator examples, with indirect impact:

— Primary material resources (mass) used in procured road-infrastructure per region.

— Reused material resources (mass) in automotive sector of country X.

Indicator from this document (see A.6.2, B.6.4 and B.6.5):

— MP.

— Value per mass.

— Resource productivity.

D.4.6 SDG 11: Sustainable cities and communities

Target 11.6:

— By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

SDG indicator:

— 11.6.1: proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities.

Circularity indicator examples, with direct impact:

— Recycled paper, glass, plastic and food-waste (mass/year) per city avoiding incineration and landfill of waste material.

— Recycled E-waste (mass/year) per city.

Indicators from this document (see A.3.4 and A.3.5):

— Per cent actual recycled material derived from outflow

— Per cent actual recirculation of outflow in the biological cycle

D.4.7 SDG 13: Climate action

SDG 13 targets and indicators are linked to countries, which makes it difficult to connect circularity indicators directly to the SDG 13 indicators, with exception of the regional system level for a country.

However, circularity activities at the four system levels can contribute to reduce GHG emissions in favour of climate situations.

Circularity indicator examples, with direct impact:

— Reduced GHG emissions due to refurbishing, remanufacturing and recycling (in tons of CO_2 equivalents) per sector in country X.

— Reduced GHG emissions due to redesign of fossil fuel equipment to solar energy equipment (in tons of CO_2 equivalents) per sector in country X.

— Percentage of renewable energy for all processes, including biofuels and biogas from residual sources or co-products.

Indicator from this document (see A.3.3):

— Per cent actual reused products and components derived from outflow.

D.4.8 SDG 14: Life below water

Target 14.1:

— By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.

SDG Indicator:

— 14.1.1: Index of coastal eutrophication and floating plastic debris density.

Circularity indicator examples:

— Plastic packaging reduced (to avoid losses to rivers, lakes, seas, oceans).

— Waste pollution reduced or prevented by biodegradable products instead of non-biodegradable based products.

Indicator from this document (see A.5.3):

— Per cent water discharged in accordance with quality requirements.

D.4.9 SDG 15: Life on land

Target 15.5:

— Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.

A direct measurement connection with the related SDG indicator (15.5.1: Red List Index) is difficult to define. However, indirect impact of circularity activities to biodiversity can be measured, see the following examples.

Circularity indicator examples, with indirect impact:

— Reduced hazardous releases to soil and air in replacing chemical pesticides by biodegradable pesticides, avoiding toxic diseases for insects and birds.

— Reused wood (pallet packaging, construction demolition) avoiding deforestation (number of trees/year).

— Use of biological material from agricultural production methods that regenerate biodiversity.

— Percentage of materials that have been safely returned to environment through composting, biodegradation or nutrient recirculation.

Indicator from this document (see A.2.4):

— Average renewable content of an inflow.