CIRCULAR TRANSITION INDICATORS V4.0

Metrics for business, by business

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Thank you to the companies and organizations that have contributed to the development and implementation of the Circular Transition Indicators.

Advisory group

The Circular Transition Indicators framework is developed by members of the Circular Transition Indicators project of WBCSD's Products & Materials Pathway.

The Circular Transition Indicators are co-authored by KPMG

We are proud to continue to partner with WBCSD to further business progress toward a more circular economy. As a participant in the Circular Transition Indicators project, we helped identify tools to better self-assess our use and reuse of resources. We can now prioritize and establish targets to monitor our progress within the circularity space.

Stephan B. Tanda
President and CEO, Aptar

At CHEP, we know that our share & reuse business model is inherently circular. The challenge is how to measure it! We initially welcomed the CTI Tool with a view to finding a company-wide circular performance KPI. We soon realized it is actually much more and also found their approach to material flows analysis complement other circularity measurement systems. We are also able to quickly identify risks at an appropriate level of detail and prioritize actions to improve our circularity.

Juan Jose Freijo
Vice President, CHEP

Transforming towards sustainable mobility the Mercedes-Benz way means taking the lead in electric drives while at the same time taking on responsibility as a company and in terms of products and production. Therefore, we drive the conversion of the value chain into a value cycle, to get closer to our goal of CO_2-neutral mobility. By implementing the CTI framework into our business structures, we are able to measure and improve the circularity of our processes in a comprehensive and standardized way in order to derive appropriate measures to accelerate our transformation into a circular economy.

Markus Schäfer
Member of the Board of Management, Mercedes-Benz AG

KPMG is proud of our continuous involvement in the development of the CTI Framework v3.0. As an implementation partner we see the added value that this framework brings to our clients to help assess circular performance, identify risks and opportunities and steer towards resilient and future-proof business practices.

Richard Threlfall
Global Head of KPMG IMPACT, KPMG International

The circular economy is not just about recycling – it is about a transformation of the entire value creation system by decoupling growth from finite resources. At LANXESS, we support this transformation. Being in the middle of long value chains, we are not only working on alternative raw materials, but are also exploring different recycling technologies for our products. For example, our engineering materials are suitable for mechanical and multiple chemical recycling pathways.

Anno Borkowsky
Board member responsible for value-chain circularity, LANXESS

I believe in the circular economy. Today Holcim is one of the world's leaders in this area, recycling 50 million tonnes of waste into our products and processes. By 2030, I set the target to double this rate, to recycle 100 million tonnes across our business. I see a big opportunity in recycling construction and demolition waste, as concrete can be infinitely recycled. Using WBCSD's Circular Transition Indicators (CTI), we are closing material loops and measuring our revenue from green products and solutions. With the CTI framework we are actively measuring our contribution to building greener cities to keep on raising the bar.

Jan Jenisch
CEO, Holcim

The Circular Transition Indicators (CTI) framework developed by the World Business Council for Sustainable Development (WBCSD) provides a universal global definition and measurement method to make circular entrepreneurship understandable, measurable and manageable. The framework brings us the right focus and encouraged us to move from a waste-report to an inflow-report and outflow-report. For example, at this moment we use the framework to measure the level of circularity of our trains, and to steer decision-making during procurement to achieve our goal: 100% circular trains in 2030.

Marjan Rintel
CEO, NS

The Port of Rotterdam, as a key hub for resources in Northwestern Europe, has used the CTI framework to assess the circularity of production and throughput in the port. This exercise has resulted in a baseline for improvements in the future. The scan made it clear that there is enormous potential to improve the circularity of our port and industrial cluster. The circular economy is an increasingly important component of our strategy and we are actively working with our partners to make supply chains more circular.

Allard Castelein
CEO, Port of Rotterdam

Security Matters (SMX) supports and acknowledges the leadership role of WBCSD and the importance of the Circular Transition Indicators (CTI) framework as it complements SMX's digital twin technology and blockchain platform solutions enabling companies to successfully transition to a truly circular economy in a tangible, credible and measurable way – where every material is fully utilized and nothing goes to waste.

Haggai Alon
CEO, Security Matters Ltd

Transitioning to a circular economy is about much more than just reducing the waste inherent in the linear economy. It's about sustainable growth that creates economic opportunities, environmental and social benefits and increases business resilience. This transition requires a systemic shift that closes, optimizes and values resource loops across the value chain which makes collaboration across companies pivotal.

Alistair Field
CEO, Sims

Foreword

Circularity must be accelerated to optimize resource use and enable the systems transformation required for sustainable production and consumption. A net-zero, nature-positive world can't be delivered without significantly growing the circular economy. The developing accountability systems for Climate and Nature are accelerating business commitments to a low-carbon, nature-positive world. Equity is closely following. The circular economy, through the adoption of circular sourcing and design strategies, longer and multiple product lives, and the closing of resource loops, is a fundamental building block of the transformations we need for a world where more than nine billion people can live well within the limits of the planet, by 2050.

Companies can reduce risks, maximize resource value and develop organizational resilience while mitigating climate change and reducing pressures on nature by increasing circularity. Moving from linear to circular economic models requires the adoption of new metrics to drive progress in circularity.

Built for business, by business, the Circular Transition Indicators (CTI) provide a reliable framework of metrics that companies can use to develop insights into how to increase circularity along their value chain and understand how that reduces their impact on climate and nature.

We know that the environmental benefits of a circular economy are extensive. To date, however, businesses have struggled to measure the effect of circularity on reducing carbon emissions and preserving nature.

In this updated version of CTI, we have extended the greenhouse gas (GHG) impact methodology to provide a more complete picture of how circularity can affect the carbon footprint of a company's products and materials. The updated methodology draws from widely adopted carbon accounting practices and focuses on incentivizing the reuse of products and materials across value chains.

In CTI v4.0 we begin the journey toward quantifying the impact of circularity on nature, where business has a critical role to play in protecting and restoring natural systems. This requires fundamental changes in the way we extract, produce and consume resources but promises to deliver great benefits in halting and reversing nature loss. For example, a landmark report by Sitra estimates that a shift to a circular food and agriculture sector can deliver up to 73% in biodiversity recovery by 2035.

Up to 75% of the Earth's land surface has been significantly altered by human actions to meet the growing demand for food, fuel, and raw materials.[1] The adoption of circular practices in materials sourcing is a critical step in ensuring healthy ecosystems and life on our planet. CTI v4.0 will help companies assess how regenerative production and minimizing resource extraction can reduce impacts on land use, the most impactful driver of nature loss.

Since the inception of CTI, thousands of companies are now using consistent circular metrics to transform their business toward building resilience, unlocking new growth opportunities and pathways to value generation, delivering on their sustainability roadmaps and developing readiness toward accountability systems for circularity and sustainability.

We welcome you with us on this transformational journey!

Diane Holdorf
Executive Vice President, WBCSD

Executive summary

ANNOTATIONS

- NEW CONTENT
- EXAMPLES
- NOTES

As the circular economy builds momentum, it is imperative for companies to prepare for their transition based on insights into their circular performance and associated risks and opportunities. To do this, business needs a universal and consistent way to measure its circularity.

According to the Circularity Gap Report, the global economy is only 7.2% circular today.[2]

The Circular Transition Indicators (CTI) shaped by 30 WBCSD member companies help answer questions like:

- How circular is my company?
- How do we set targets for improvement?
- And how do we monitor improvements resulting from our circular activities?

CTI is simple, applicable across industries and value chains, comprehensive yet flexible, complementary to a company's existing sustainability efforts and agnostic as to material, sector or technology.

Central to CTI stands a self-assessment that determines a company's circular performance. It focuses primarily on the circular and linear mass that flows through the company, in which design, procurement and recovery models are crucial levers to determine how well a company performs.

In addition to the ability to close the loop, CTI provides insights into overall resource use optimization and the link between the company's circular material flows and its business performance.

The framework does not evaluate absolute environmental and social impacts. However, it gives insights into how circularity helps to achieve sustainability objectives related to climate and nature. This shows the circular economy as a key enabler in reaching sustainability objectives.

Although the use of common indicators for circular performance is essential to accelerating the transition to the circular economy, the value of CTI for a company goes beyond the calculation in the guidance, analysis and explanation for how circularity drives company performance. The CTI process helps companies scope and prepare the assessment and interpret its results, understand its risks and opportunities, prioritize actions and establish SMART targets to monitor progress.

CTI is inward-facing, objective, quantitative and based on demonstrable data. This data may sit in hidden corners of the company or even outside the company, with its value chain partners. In order to support and guide companies through this process, we have partnered with Circular IQ to develop the CTI Online Tool available at www.ctitool.com. Through the tool, CTI initiates value chain discussions, which are essential to accelerating the transition to the circular economy. As customer, investor and regulatory pressures to demonstrate circular performance increase, it is in each company's best interest to respond credibly.

CTI delivers a framework to prepare this response. The framework does not provide a rating but leaves it to the company to determine whether the results are in accordance with its ambitions, putting the company in the driver's seat of its own circular transition.

We invite companies of all sizes and industries worldwide to demonstrate their commitment to the circular economy by measuring their circular baseline with the launch of this updated version of CTI in May 2023.

CTI VERSION 4.0: WHAT'S NEW

CTI v4.0 includes updates to its Impact of the Loop module which helps companies prioritize circular strategies in light of their impact on the company's sustainability targets.

In this version, we update greenhouse gas (GHG) impact with a methodology to measure the impact of using higher value inflows (reused, refurbished, remanufactured content) and enabling the recovery of outflows on material carbon footprint.

CTI v4.0 includes a new indicator to measure impact on nature. CTI v4.0 begins this important work focusing on a key pressure on nature loss: land use. This report provides a methodology to measure land use impact of circular sourcing strategies.

If you have already completed an assessment with CTI, the new content will not affect your performance. CTI has only become easier and more valuable with these changes.

Part 1.

Circular Transition Indicators: Framework

Circular Transition Indicators

Today the world is only 7.2% circular.[3] Not only is it clear that this is not sustainable, the urgency to step away from a take – make – waste economic model is growing. It will be virtually impossible to achieve the Sustainable Development Goals (SDGs) and the Paris Agreement if this wasteful trend continues, as we will need the natural resources of two Earths by 2030.[4] Business must step up action to deliver solutions for a net-zero emissions, nature-positive and equitable world.

Where some see waste, we see value, opportunity and a business case to use resources for as long as they can last. As the pressure to shift from linear to more circular ways of doing business increases, the good news is that the opportunity to improve stands at over 91%.

The momentum to transition is growing and both the private and public sector are beginning to set ambitious circular targets.

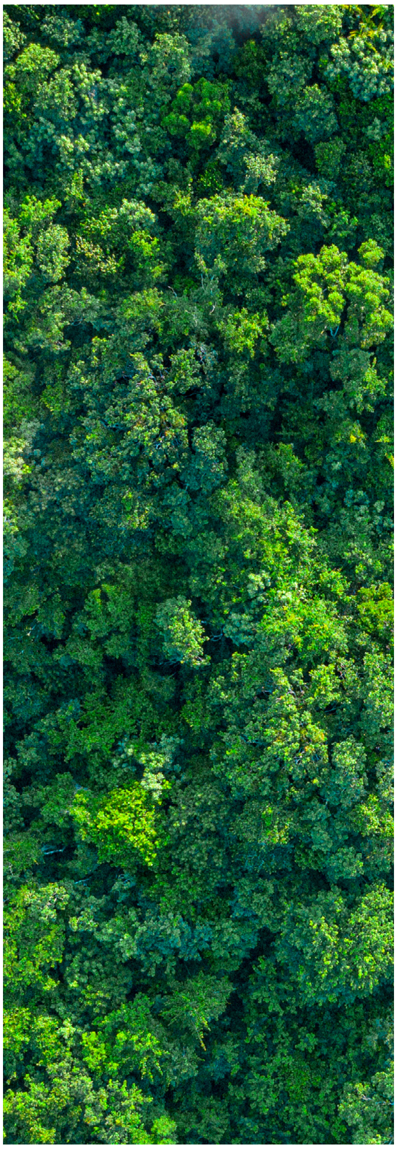
For example, the European Commission is promoting an accelerated transition and the Netherlands introduced a government-wide program to reduce primary raw material use by 50% by 2030 and transition to a full circular economy by 2050.

Transparency and alignment are critical to establishing a common language across industries and governments to develop strategies and measure progress. For this reason, 30 global companies have come together through WBCSD's Products and Materials pathway to develop the Circular Transition Indicators (CTI).

We have developed an objective, quantitative and flexible framework, identifying risks and opportunities to determine circular priorities and set targets. We do not intend for this framework to replace existing sustainability frameworks already used by industry; rather, we endeavor to provide additional insights into circularity performance.

This CTI framework is based on an assessment of material flows within company boundaries, combined with additional indicators on resource efficiency and efficacy, as well as the value added by circular business.

Through this lens, the framework can guide companies in gaining concrete insights into how they can most effectively transition to a circular economy and the associated opportunities.



Need for circular metrics

Linear business models have been profitable for decades. However, with finite natural resources and the increasing cost of externalities, companies are increasingly exposed to market, operational, legal and business risks. At the heart of the business case for circularity sits the opportunity for companies to create more value by being smarter about how they use resources. Through circular business models, companies can accelerate growth, enhance competitiveness, and mitigate risk.

TRANSITION

While a circular economy is an economic model that provides opportunities for companies across industries, the transition to a circular economy is not straightforward. Companies must change business models, adapt strategies and evolve the skills of their workforces, and governments must adjust policies to enable the circular economy.

This makes it difficult to plan for and set clear targets for a coordinated transformation. To understand where a company currently stands in its circularity and allow for the setting of targets monitored by clear key performance indicators (KPIs), companies need a system of metrics that can guide their decision-making when adopting circularity in their corporate strategy.

ONE COMMON APPROACH

No company can drive the transition to a circular economy on its own.

The circular economy requires a larger industry, value chain and cross-sector effort. To transform, companies must speak the same language, regardless of size, industry or value chain position.

Having a common approach to measuring and monitoring circular performance is essential. This will allow value chains to become value cycles, progressing towards a shared vision.

This initiative started as the Circular Metrics Landscape Analysis,[5] in which we carefully studied and reviewed existing protocols and standards for circular metrics. The analysis and subsequent conversation identified several ways to calculate circularity, such as the Material Circularity Indicator and Circulytics by the Ellen MacArthur Foundation;[6] and Circularity Gap Report Initiative by Circle Economy[7] or the Circularity Check by Ecopreneur.eu for a qualitative circularity self-assessment.

These methodologies converge on material flows – establishing a common language for circularity across industry and government.

The analysis concluded that there was an existing need for an inward facing, quantitative approach and guidance to measure circularity for the whole company, business unit or product (group) with a framework that complements assessments and tools used by companies today. Building upon material flows, CTI incorporates water, renewable energy and business value into its scope to create a multidimensional perspective of a company's circular performance.

CIRCULAR ECONOMY DEFINITION

The circular economy is an economic model that is regenerative by design.

The goal is to retain the value of the circulating resources, products, parts and materials by creating a system with innovative business models that allow for renewability, long life, optimal (re)use, refurbishment, remanufacturing, recycling and biodegradation.

By applying these principles, organizations can collaborate to design out waste, increase resource productivity and maintain resource use within planetary boundaries.

Note: CTI is in alignment with the Ellen MacArthur Foundation circular economy principles:

- Design out waste and pollution
- Keep products and materials in use
- Regenerate natural systems.

Use of CTI

CTI offers companies insights into their circular economy performance, allowing them to:

- **Identify circular opportunities and linear risks**, with the aim of improving company longevity and resilience
- **Set a baseline and monitor progress** on their circular transition
- **Respond to customers and external stakeholders** (e.g., investors or civil society organizations)
- **Start value chain conversations** on shared circular priorities
- **Attract new business** by simultaneously advancing customers' circular objectives
- **Prepare for disclosure** to regulatory standards on circularity (e.g., the EU Corporate Sustainability Reporting Directive or GRI 306).[8]

We designed this framework to be easy to implement and versatile in scope. It allows business to measure circularity at any level, from product and product level to the entire business, so that companies can use the indicators at the level that best suits their business.

With CTI, we aim to empower companies in their circular transition by allowing them to better understand their circular economy potential.

As such, we endeavor to be as non-prescriptive as possible.

WBCSD does not play a role in a company's CTI assessment, which it developed as an inward-facing tool for companies to gain insights into their circularity. As such, CTI does not:

- **Constitute an assessment of sustainability performance.** Through the latest additions to the Impact of the Loop module, CTI is now able to estimate the impact of circular economy interventions on sustainability targets and, hence, can be seen as complementary to existing and commonly used frameworks that cover a company's wider sustainability performance (e.g., greenhouse gas (GHG) emissions, biodiversity, human capital, etc.).
- **Compare industries, companies or products.** Each company's circularity journey is unique. It is therefore only possible to make comparisons in a relevant context and upon careful consideration.
- **Target non-sustainability marketing and promotional materials.** Circular economy is an important and necessary pathway to more sustainable production and consumption.

However, its influence on a company's sustainability performance depends on the larger context of other sustainability indicators. Companies are discouraged from communicating the results of the framework externally unless they present them in the appropriate context.

SHARED PRIORITIES

One of the key drivers behind the aluminum industry's highly effective recycling infrastructure was a coalition of aluminum value chain stakeholders that realized the material was at risk of both depletion and reduced competitiveness if linear consumption rates continued their trajectory. Their combined commitment and resources to develop a powerful recycling infrastructure lay at the core of today's 70% recovery rate for aluminum cans.

In 2015, the Aluminium Stewardship Initiative (ASI) incorporated as a non-profit entity to develop and operate an independent third-party certification program to drive a material stewardship approach for aluminum throughout the value chain.

Source: Aluminium Stewardship Initiative

We consider the following to be an appropriate context:

- The company carefully discloses the scope of the assessment to give the reader a comprehensive view of its circularity performance;
- The company clearly states that the "Circular Transition Indicators are not a full-scope sustainability assessment and that results should not be used to benchmark companies or industries on their full scope sustainability performance";
- An independent third party assures the results.

For product-level circularity, we encourage companies to disclose the scope of the assessment and how it compares to the rest of the company's portfolio.

THE CTI ONLINE TOOL

Data is a crucial ingredient in CTI. This includes data that may be readily available, as well as data hidden in pockets of the company or even data that exists outside your company with supply chain partners. Obtaining this data and performing the calculations constitute the most resource-intensive parts of the framework.

To optimize CTI accessibility and usability, we have partnered with Circular IQ to develop the CTI online tool: www.ctitool.com.

This tool structures data collection and calculates the outcome per indicator.

It includes functionality that can support users as they contact internal stakeholders or value chain partners for data requests to avoid confidentiality issues.

Additionally, it documents the exact scope and steps taken, allowing for consistency and monitoring over subsequent cycles. The CTI online tool serves a facilitating function and stores outcomes in a structured manner; it supports decision-making and allows companies to keep track of progress. However, we recommend that companies first read the methodology and user manual within this document for optimal results and a smooth process. Further, we recommend to involve different experts from the company in the implementation of CTI's seven steps rather than attempting to complete the tool in isolation.

The CTI online tool guarantees data security and confidentiality[9] and we are continuously improving it for user experience and actionable and meaningful outcomes.

FRAMEWORK PRINCIPLES

Simplicity

Be as simple as possible within the context of the circular economy.

Consistency

Use one common, cross-industry language and provide consistent insights into circular opportunities and linear risks regardless of organization size, sector or value chain position.

Completeness and flexibility

Offer a complete set of metrics with the flexibility of accommodating diverse business needs.

Complementarity

Given that circularity is one pathway to more sustainable production and consumption, assessments should never take place in isolation and should always complement other existing sustainability and business metrics.

Neutrality

Refrain from prioritizing specific materials over one another insofar as they all contribute to the circular economy.

A value chain effort

The circular economy requires collaboration. The entire value chain must work together to maximize the value created for every unit of resource.

Figure 1 illustrates a simplified value chain. The further a company is from the red arrows, the more difficult it can be to obtain information.

CTI is a catalyst in the initiation of cross value chain conversations. It provides a process for value chain partners to collectively pursue shared goals.

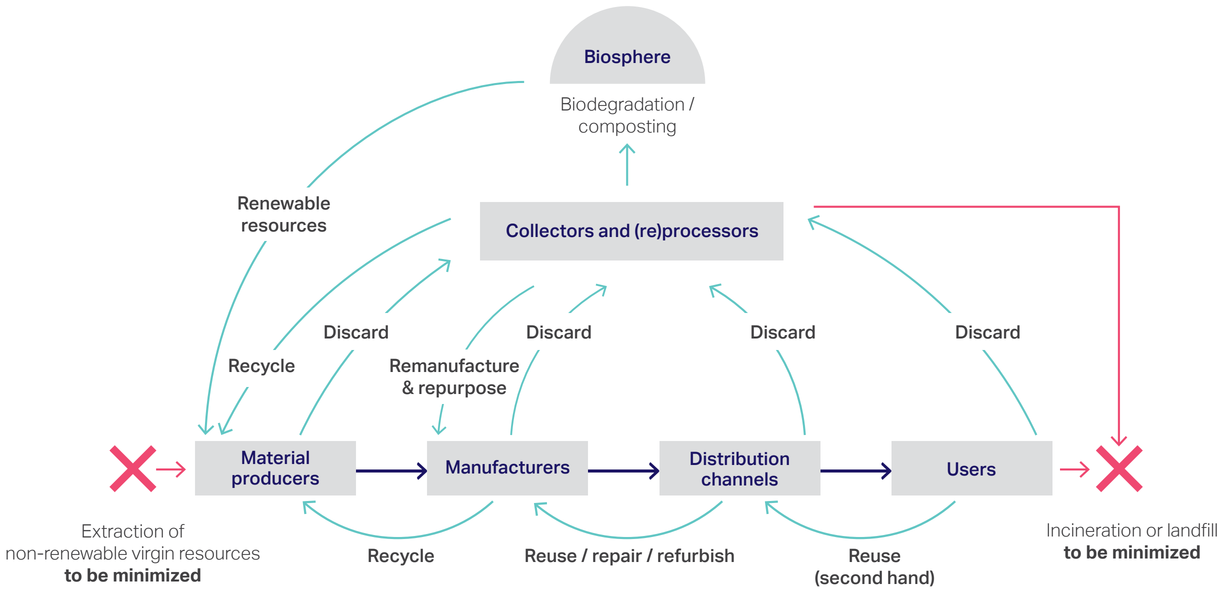
The CTI online tool helps companies obtain required data from value chain partners without raising privacy or confidentiality concerns.

SHARED PRIORITIES

A Dutch telecom company engages with its supplier through a Circularity Manifesto, ensuring upstream value chain partners conduct their business in the same circular way the telecom company does.

Source: KPN Circular Manifesto and Appendix 2017

Figure 1: Simplified representation of the value chain recovery system



The CTI methodology logic

CTI is based on material flows through the company. By analyzing these flows, the company determines its ability and ambition to minimize resource extraction and waste material. It entails the assessment of the flows within the company's boundaries at three key intervention points:

INFLOW

How circular are the resources, materials, products and parts sourced?

OUTFLOW – RECOVERY POTENTIAL

How does the company design its products to ensure the technical recovery of components and materials at a functional equivalence (e.g., by designing for disassembly, repairability, recyclability, etc.) or that they are biodegradable?

OUTFLOW – ACTUAL RECOVERY

How much of the outflow does the company actually recover?

The outflow includes products, by-products and waste streams. Companies can improve actual recovery rates through closed loop business models or mandatory or voluntary open loop recovery scheme efforts.

The results will illustrate how effectively a company closes the loop.

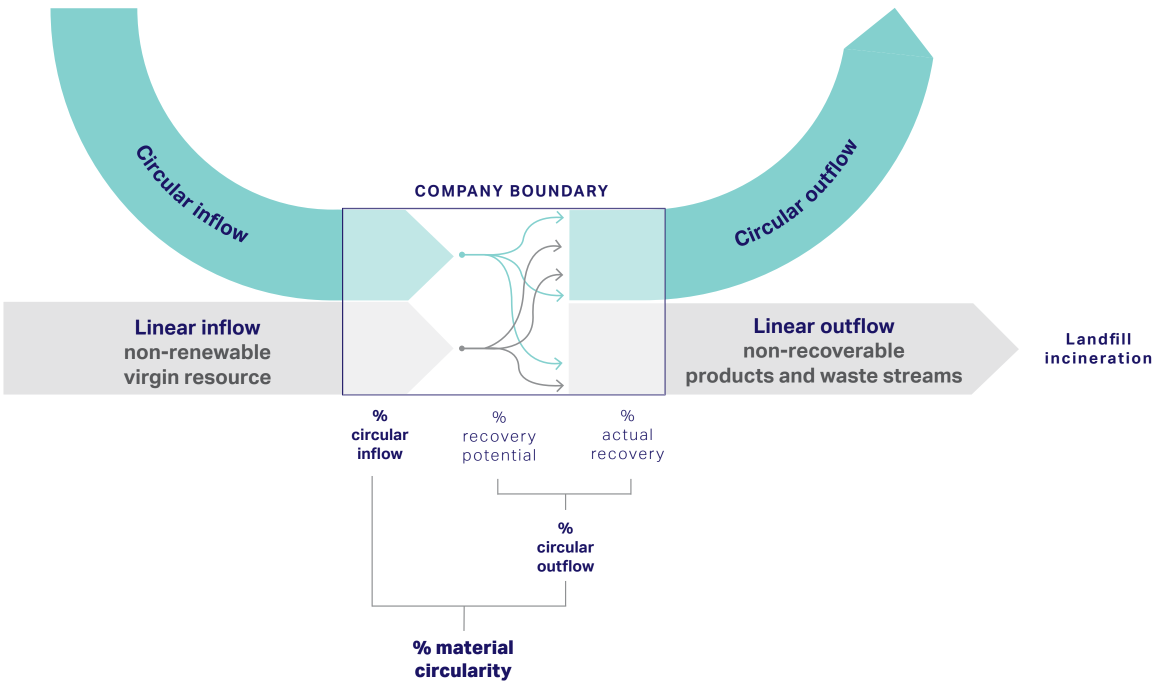
MATERIAL FLOWS

Material flows can include nutrients, compounds, materials, parts, components or even products. For readability, this report refers to all of these as material flows.

RECOVERY

Recovered refers to the technically feasible and economically viable recovery of nutrients, compounds, materials, parts, components or even products (depending on the organization) at the same level of functional equivalence through reuse, repair, refurbishment, repurposing, remanufacturing, recycling, biodegradation (including composting).

Figure 2: Illustration of material flows



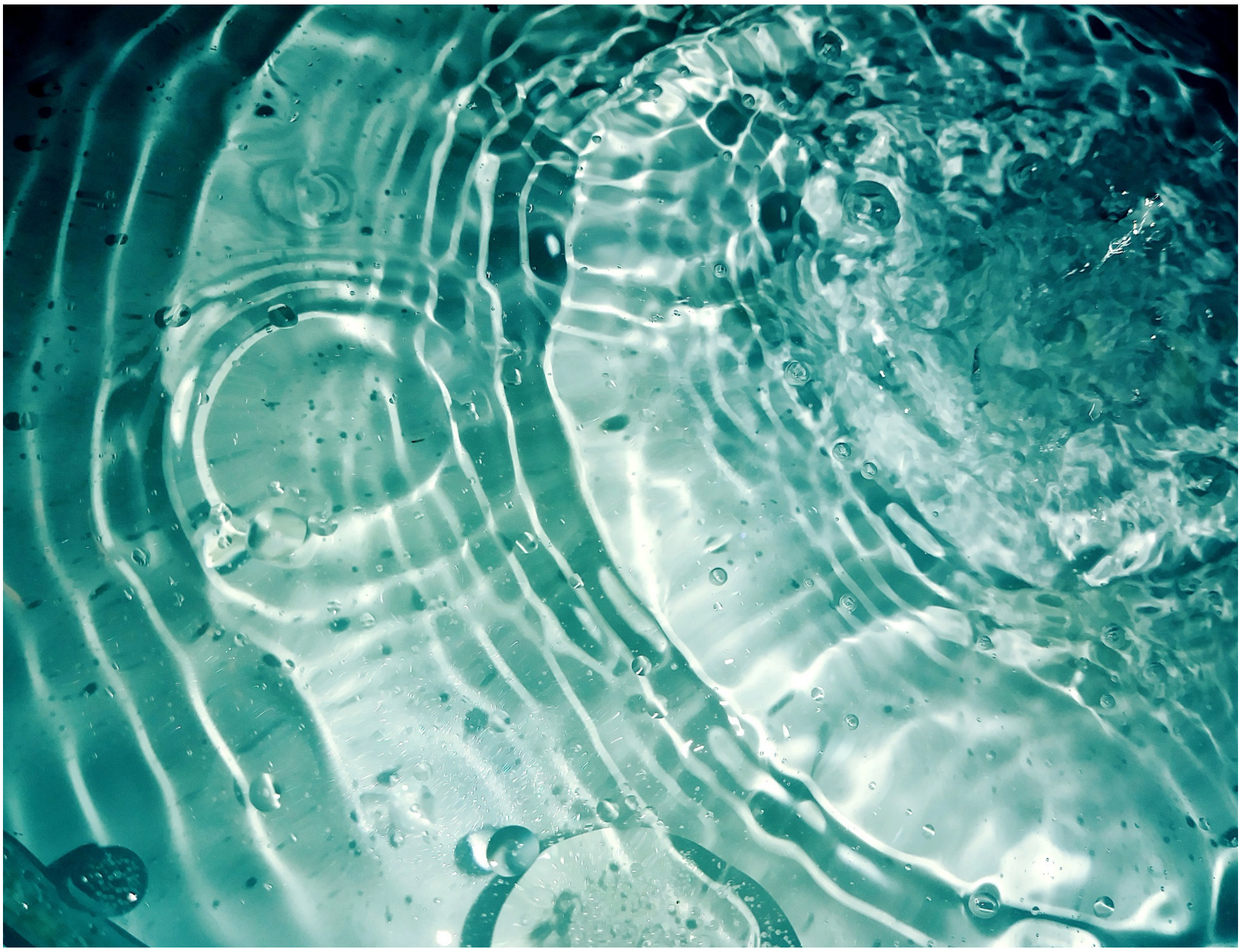
The indicators

Any company, regardless of size, sector or position in the value chain, can use this framework. As such, the selection of indicators relevant for any business will vary. CTI provides a menu of indicators, some of which are optional.

Assessments start with the completion of the full Close the Loop module. Companies may then calculate indicators from Optimize the Loop and Value the Loop for additional insights.

Impact of the Loop is a new module that helps companies measure the impact of circular strategies on their sustainability.

Close the Loop	Optimize the Loop	Value the Loop	Impact of the Loop
% material circularity	% critical material	circular material productivity	GHG impact
% water circularity	% recovery type	CTI revenue	nature impact
% renewable energy	actual lifetime		
	onsite water circulation		



1. CLOSE THE LOOP

This module calculates the company's effectiveness in closing the loop on its material flows.

This can be assessed on the level of the company, a business unit, facility or product (group) level.

% material circularity

A company's performance in closing the loop is expressed in % material circularity, which is the weighted average between % circular inflow and % circular outflow, as outlined in the formula structure below. The % circular inflow is determined by the % non-virgin content and % renewable content (sustainably grown bio-based sources). The % circular outflow is determined by the % recovery potential (which is focused on design) and the actual recovery. These three pillars address different aspects of the business: procurement for inflow, design for potential recovery and business model innovation (closed) and legal and partnerships (open) for the actual recovery.

BIOLOGICAL CYCLE GUIDANCE

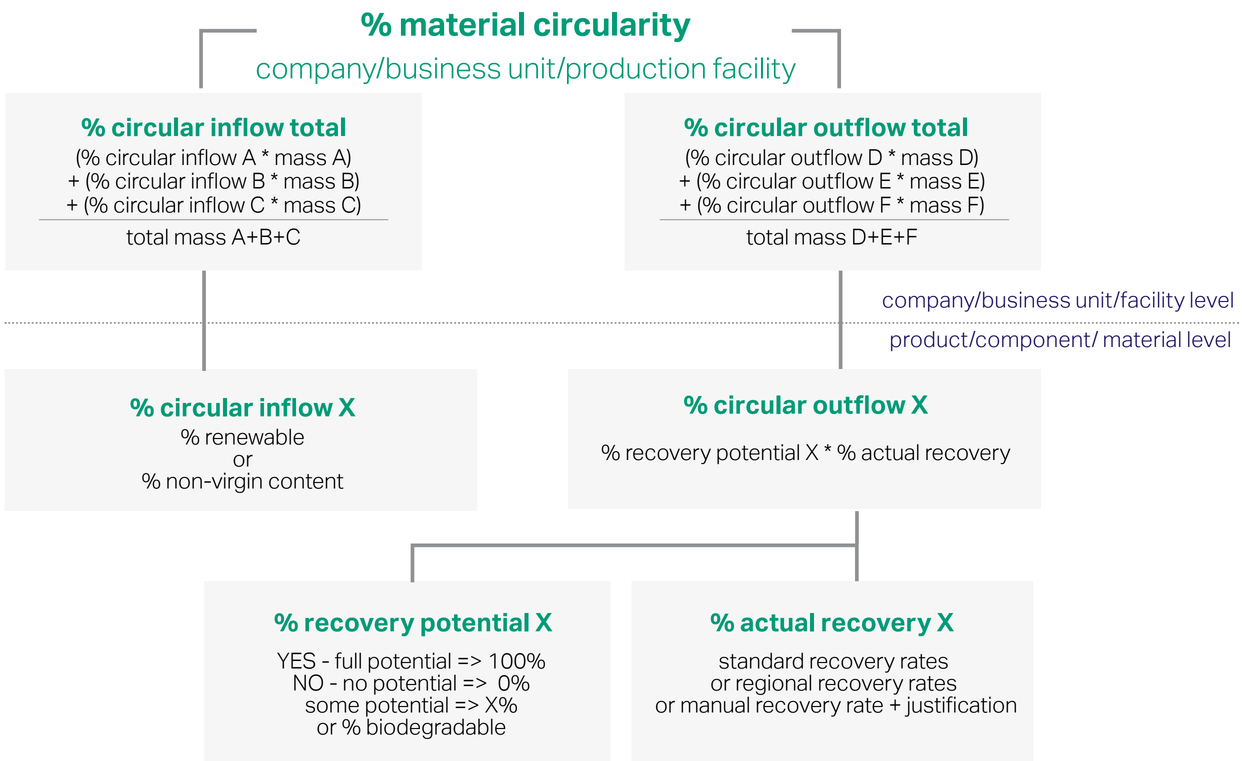
CTI includes specific guidance for the assessment of materials in both technical and biological cycles.

SEPARATE INDICATORS

The resulting outcomes from the Close the Loop module are:

1. % material circularity, which is the weighted average of:
   - % circular inflow
   - % circular outflow
2. % water circularity
   - % circular water inflow
   - % circular water outflow
3. % renewable energy

Figure 3: % material circularity



Water circularity

In addition to material flows, we consider the circularity of freshwater to be an important element of the circular economy. What sets water apart from other materials and resources is the scale of the relevant ecosystem. Where materials can circulate in a global system, it is necessary to assess water circularity on a local level for a water catchment area or local watershed. The purpose of water circularity is to lower freshwater demand and ensure water resource availability for all users and the environment. Circularity of water is therefore determined through the % circular water inflow and % circular water outflow, which in turn depend on local water conditions.

Context-based indicators

% water circularity

$$\% \text{ water circularity} = \frac{\% \text{ circular water inflow} + \% \text{ circular water outflow}}{2}$$

% circular inflow total

$$= \frac{\text{Q total circular water withdrawal}}{\text{Q total water withdrawal}} \times 100\%$$

% circular water outflow (discharge, restore)

$$= \frac{\text{Q total circular water discharge}}{\text{Q total water withdrawal}} \times 100\%$$

In addition, the water circularity section offers an internal-facing indicator focusing on internal facility circulation through reuse and recycling.

Internal indicator

Onsite water circulation (reuse & recycle)

$$= \frac{\text{Q water use - Q total water withdrawal}}{\text{Q total water withdrawal}} + 1$$

Renewable energy

The circular economy requires the transition to renewable energy. As most companies already have metrics in place to measure renewable energy consumption for business operations, CTI considers energy separately for which companies can use this existing data. The % renewable energy calculation is as follows:

% renewable energy

$$\frac{\text{renewable energy (annual consumption)}}{\text{total energy (annual consumption)}} \times 100\%$$

WORKING GROUP FOR METRICS FOR WATER CIRCULARITY

WBCSD and BIER (Beverage Industry Environmental Roundtable) combined their expertise to develop a solid and meaningful set of indicators to assess the circularity of water at the facility level. Supplementary guidance and a water circularity metrics tool that provides more granular detail and guidance on the water indicators are available from WBCSD and BIER.

Consult the water metric guidance and tool.

2. OPTIMIZE THE LOOP

This module provides insights on material criticality, resource-use efficiency and higher value recovery strategies. This module and its indicators are optional.

Critical materials

The **% critical inflow** highlights the share of the inflow considered critical. Companies can refer to internal critical materials lists or existing public lists such as those compiled by the European Commission or the United States Geological Survey.[10] This allows companies to assess the risk level of specific material flows and to prioritize accordingly.

The calculation is:

% critical inflow

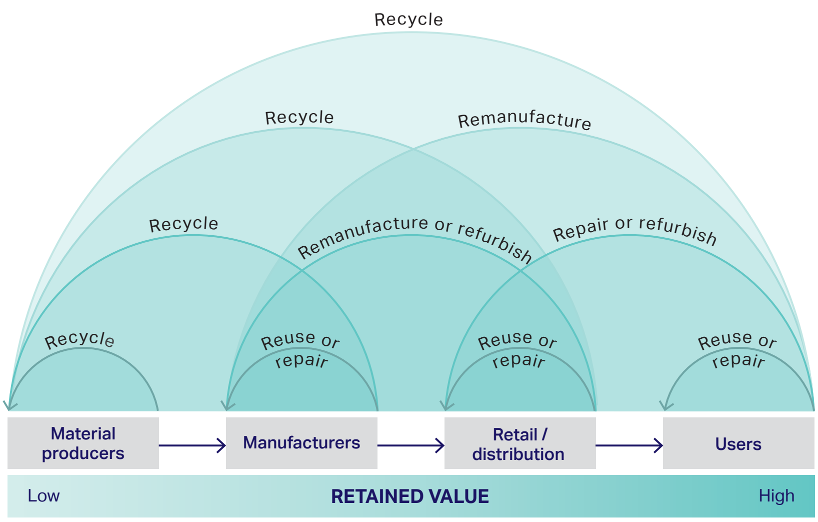
$$\frac{\text{mass of inflow defined as critical}}{\text{total mass of linear inflow}} \times 100\%$$

Recovery type

The other indicator of the Optimize the Loop module, **% recovery type,** focuses on how the company recovers outflow and recirculates it into the value chain. Recovery type is applied to % actual recovery. The results provide a breakdown of the recovered outflow in shares reused/repaired, refurbished, remanufactured recycled or biodegraded. The CTI online tool automatically generates this breakdown based on the Close the Loop data entered.

Depending on the value chain position of the company, the possibilities for optimization in recovery loops may vary.

Figure 4: Recovery types and retained value



CASCADING

CTI includes a model for cascading in the technical sphere and one for the biosphere.

Lifetime extension strategies such as reuse, refurbish or remanufacture are considered to be recovery strategies that retain higher value as they allow companies to preserve the economic value embedded in products and materials, slow down resource flows, and reduce waste and negative environmental impacts. While recycling is a circular strategy under recovery type, it does not lead to lifetime extension. As a preference, lifetime extension strategies should be considered above recycling whenever possible.

To encourage companies to consider lifetime extension strategies whenever available, CTI v3.0 provides the **% recovery by lifetime extension** sub-indicator to help companies track their performance across strategies aimed at retaining higher value: reuse, refurbish and remanufacture.

Actual lifetime

Longer design lives and the lifetime extension of products contribute to slowing down the overall flow of resources, reducing environmental impacts and the production of waste while preserving the economic value embedded in products and materials.[11]

CTI recognizes design for longevity and lifetime extension of products as a circular practice. Designing durable products and materials and implementing strategies to extend their lifetime once they become obsolete leads to higher circularity and value retention through the life cycle of materials and products.

A product's lifetime is intended as the duration of the period that starts at the moment a product is released for use after manufacturing or recovery and ends at the moment a product becomes obsolete.[12] Its durability, intended as the ability to "function as required, under specified conditions of use, maintenance and repair, until a limiting event prevents its functioning", drives longer product lifetime.[13]

A product's technical lifetime and functional lifetime enable its durability. The technical lifetime is the time span or number of usage cycles for which a product is considered to function as required, under defined conditions of use, until a first failure occurs. Functional lifetime is the time a product is used until the requirements of the user are no longer met, due to the economics of operation, maintenance and repair or obsolescence. While the technical lifetime is part of the intrinsic properties of the product, the conditions created around the product determine its functional lifetime.[14]

NOTE

In designing products for longevity and exercising product lifetime extension strategies, companies should ensure that these do not do significant harm to efforts to mitigate and adapt to climate change, the sustainable use and protection of water and marine resources, pollution and prevention control, and the protection and restoration of biodiversity and ecosystems. For more background, companies may refer to the European Commission's Do no significant harm (DNSH) principles or other similar regional, national, sector or industry directives.

EXAMPLE

A computer mouse is designed to last 6 years but the average lifetime of a computer mouse is 4.5 years. The actual lifetime indicator in CTI will provide a positive score for companies whose computer mouse stays in use demonstrably longer than the industry average. (Lifetime data source: Product Life Database, International Living Future Institute).

NOTE

For more context on product lifetime, its impact on slowing the loop and relevant policies and strategies refer to the Product Lifetime Extensions Working Group's reports under UNEP Circularity Platform.

These conditions facilitate the repairability, upgradability and reusability of products extending their useful life. We have developed CTI's **actual lifetime** indicator with the intention of driving companies to develop an understanding of a product's average life duration.[15] This means the duration of life that the product actually experiences, on average, rather than design life or warranty period.

The actual lifetime indicator provides a higher score for products that stay in use for longer than the industry average and is calculated as follows:

actual lifetime

$$= \frac{\text{product actual lifetime}}{\text{average product actual lifetime}}$$

Companies can measure lifetime in number of years OR number of use cycles.

3. VALUE THE LOOP

This module illustrates the added business value of a company's circular material flows. The indicators are optional.

While the Close the Loop and Optimize the Loop modules focus on material flows, the Value the Loop module goes beyond material flows to address how circularity creates maximum value with minimum resources.

Circular material productivity

This indicator illustrates the company's effectiveness in decoupling financial performance and linear resource consumption. Companies can calculate circular material productivity by dividing revenues generated by the mass of linear inflow as considered in the Close the Loop module.

The calculation is:

circular material productivity

$$\frac{\text{revenue}}{\text{total mass of linear inflow}}$$

The greater the circular material productivity, the better a company is at decoupling financial performance from linear resource consumption. Insights stem from looking at historic data to understand the evolution of material productivity and by monitoring progress over time to demonstrate a decoupling (or increasing dependency).

CTI revenue

Financial institutions increasingly recognize the value that the circular economy presents in terms of risk mitigation, financial opportunity and positive environmental and social impacts. A solid grasp of value created through circular investments allows investors to proactively recognize and reward companies that make progress on circularity.

However, the lack of a consistent methodology to measure circular performance in terms of both resource efficiency and its associated financial benefits has served as a barrier in scaling up circular investments.

Using the Close the Loop results, a company measures its circular CTI revenue by multiplying the sum of a product (group) or business unit's weighted average of the % circular inflow and % circular outflow and multiplying that by the revenue generated by that product (group) or business unit. As outlined under Close the Loop, calculate both % circular inflow and % circular outflow based on weight of the material flows.

In other words, a company's CTI revenue is its revenue adjusted for the % material circularity of its product portfolio. To calculate CTI revenue for a product:

CTI revenue (product)

$$\left[\frac{(\%\ \text{circular inflow} + \%\ \text{circular outflow})}{2}\right] \text{X revenue}$$

To calculate CTI revenue for a business unit or company, sum up all product CTI revenues calculated:

CTI revenue (company)

CTI revenue A
+CTI revenue B
+CTI revenue C +...

The greater the CTI revenue, the better a company can generate revenues from its circular products/business. This metric also reflects decoupling as revenues increase from circular flows.

The methodology is currently based on material circularity and does not provide revenue measurement for services and digital solutions.

4. IMPACT OF THE LOOP

Transitioning to a circular economy will be key to addressing the world's most pressing challenges: the climate emergency, the loss of nature and growing inequality.[16]

Moving to a circular economy offers numerous benefits for both people and planet. It has the potential to significantly reduce greenhouse gas emissions and pressure on nature by decreasing the need for new production and reducing energy consumption. It can promote social and economic equity by creating new jobs, increasing access to resources and to affordable and sustainable products. Shifting to circular approaches may involve trade-offs that companies must be aware of to maximize benefits and minimize any negative impacts. By combining impacts on GHG emissions and land use, for example, companies can capture trade-offs of switching from oil-based to bio-based inputs.

The fourth module, called **Impact of the Loop**, aims to help companies understand the impact of circular strategies on achieving sustainability objectives related to climate, nature and equity. This module measures the difference in impact between the company's current material circularity performance versus improved circularity performance, striving to achieve 100% material circularity, which – in CTI – means using 100% secondary or renewable materials and enabling 100% reuse, remanufacturing or recycling of materials and products into a next cycle through design and recovery strategies. CTI v4.0 includes methodologies to measure the impact of circular strategies on climate and nature. The next version of the CTI report will address equity.

CTI v4.0 provides an approach to understanding the impact of circular strategies on GHG emissions reduction targets. It includes a methodology to understand the circular sourcing impact on GHG emissions for reused, refurbished, remanufactured and recycled inflow and the recovery of technical outflows versus linear disposal methods (landfilling/ incineration).

Along with climate impact, companies can now start to understand how their circular performance impacts nature. Land use is the biggest driver of nature loss. Companies can help halt nature loss by switching to circular sourcing strategies.

This indicator allows for comparison between different sourcing strategies to identify the most effective circular actions in reducing land-use impacts.

GHG impact

Greenhouse gas(GHG) impact aims to provide companies with a high-level indication of the GHG emissions savings they may obtain by applying circular strategies. Circular strategies include the use of secondary or renewable materials as inflow and enabling recovery via "higher value retention" recovery such as reuse, refurbish and remanufacture or recycling of the outflow (products and materials). Companies can use this information to better understand GHG emissions savings, evaluate trade-offs and help prioritize circular improvements.

CTI v3.0 focuses on material inflow impact on GHG emissions by measuring the savings of sourcing a higher percentage of recycled content for technical materials. It provides guidance for companies to determine the difference in material carbon footprint of the current amount of recycled materials used, compared to a situation in which the inflow is composed of 100% recycled materials.

CTI v4.0 expands the GHG impact focus for circular inflow, to provide guidance on the impact of sourcing reused/refurbished products and remanufactured components on a company's scope 3 emissions accounting. Additionally, it addresses the impact of renewable (sustainably grown) biobased materials versus non-renewable (conventionally grown) biobased materials on GHG emissions. For the GHG impact of circular outflow, CTI v4.0 focuses on the difference in the impact on the material carbon footprint of enabling higher value retention recovery (reuse, refurbish, remanufacture) and recycling, versus linear disposal methods (landfill, incineration).

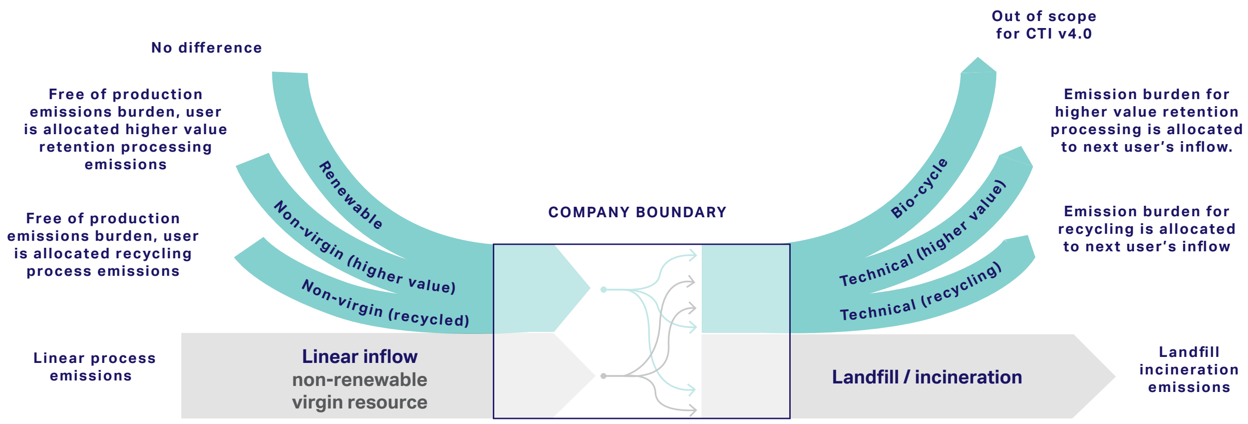
CTI v4.0 provides an approach to understanding the impact of circular strategies on GHG emissions reduction targets. It includes a methodology to understand the circular sourcing impact on GHG emissions for reused, refurbished, remanufactured and recycled inflow and the recovery of technical outflows versus linear disposal methods (landfilling/incineration).

The material flow illustration in figure 5 presents the approach developed in both CTI v3.0 and CTI v4.0 and provides an overview of material carbon footprint savings that companies may obtain by applying circular strategies.

The system model "Allocation, cut-off by classification", or the cut-off system model, is based on the recycled content, or cut-off, approach. In this system model, wastes are the producer's responsibility ("polluter pays"), and there is an incentivisation to use recyclable products, that are available burden free (cut-off).

Learn more: [https://ecoinvent.org/the-ecoinvent- cut-off](https://ecoinvent.org/the-ecoinvent-cut-off)

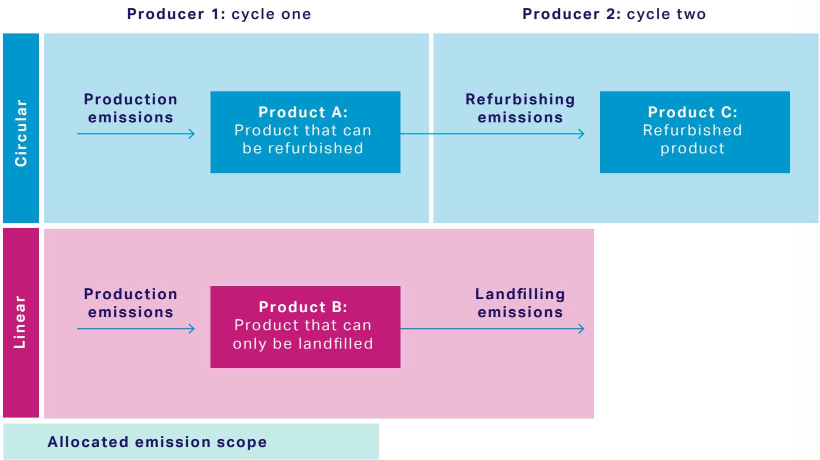
Figure 5: Material carbon footprint savings of circular strategies



To determine the GHG impact of circular flows, CTI adopted the "Allocation, Cut-off by classification" system model,[17] also referred to as "recycled content method" in the GHG Protocol.[18] In this methodology the producer of a material or product is fully accountable for the GHG emissions of the production of that material or product. The non-virgin material part or product becomes available free of burden emissions for the user of the non-virgin material or product in the next production cycle. The user of the non-virgin material or product only accounts for the GHG emissions related to the preparation for reuse or recycling processes needed. The producer also accounts for the GHG emissions of any incineration or landfilling of not recoverable material or waste. The producer of the materials or product is encouraged to make products and materials available for a next production process.

In this approach, users and producers of non-virgin materials benefit from materials that are free from the burden of production emissions while the producers of primary materials benefit from incentivizing product and material recovery to avoid high landfill and incineration emissions.

Figure 6: Allocation of emissions scope for circular versus linear scenarios



Circular process

Producer 1 is only responsible for the emissions of the primary production when the product is refurbished and used in a second production cycle. This second production cycle leads to Product C (refurbished product).

Producer 2 is only responsible for the emissions of the refurbishing process for the refurbished product (cycle two). Due to the use of the "Allocation, Cut-off by classification" methodology, Producer 2 is not responsible for the production emissions of production cycle one.

Linear process

Producer 1 is allocated the emissions of the production of Product B. Producer 1 is also allocated the landfilling emissions of Product B since the product was designed in a way that could not be refurbished and used again in a second use cycle.

EXAMPLE

GHG impact – Circular inflow

In a laptop the average amount of recycled aluminum is 60%. Based on the weight of the aluminum used in the laptop and the emissions factor per kg for both the processes related to virgin (mined) and non-virgin (recycling from scrap aluminum sourcing, there is an emissions savings of 15% on aluminum when the amount of recycled content increases from 60% to 100%.

GHG impact Circular outflow

The manufacturer of an aluminum laptop cover produces two types of laptop covers. One that is designed to be fully refurbished and used in a second cycle, one that is not designed for reuse and can only be landfilled at end of life. The two recovery strategies are compared. Based on the "Allocation, Cut-off by classification" system model, the aluminum in strategy one becomes available free of primary production emission burden for the user of the refurbished laptop cover. In that case, the user is only allocated emissions associated with the refurbishment process on the inflow side. The emissions of strategy two (landfilling), are fully accounted to the producer of the aluminum laptop cover, since the product could not be used in a second cycle, leading to a linear disposal method.

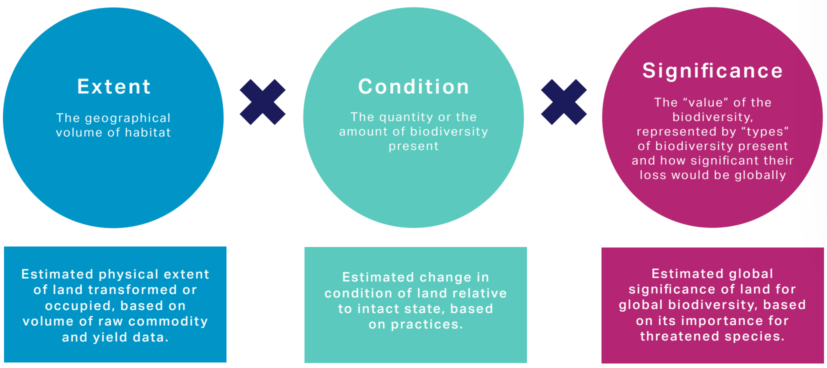
Nature impact

Biodiversity is declining at an unprecedented rate. Estimates show that extinctions are currently occurring a thousand times faster than the "natural" extinction rate.[19] Some 90% of nature loss is due to the extraction and processing of natural resources.[20] The third principle of the circular economy is to regenerate nature.[21] This can be achieved by applying regenerative production practices, extending product lifetimes, reducing waste and resource extraction.[22] Through this principle, the circular economy can reverse and halt nature loss, leaving more room for nature to thrive. Circular interventions have the potential to recover the world's biodiversity to year 2000 levels by 2035.[23]

This indicator focuses specifically on impact from land-use change. Land-use change is the most impactful driver of nature loss and includes land occupation, land-use change, land degradation and deforestation impacts.[24] This indicator will provide an initial screening of land-use impacts from the material extraction and cultivation related to a company's material inflow. It helps companies understand how their circular performance impacts nature by measuring the land-use impacts of their current inflow and potential improvement by shifting to circular sourcing. The indicator is especially relevant for companies that are highly dependent on materials that have a significant contribution to negative impacts on nature. Measuring land-use impacts is in line with the vision of a nature-positive world by 2030 and complements ongoing efforts among WBCSD members to develop the Roadmaps to Nature Positive that will deliver a tailored sectoral framework for business accountability, ambition and support the implementation of the Global Biodiversity Framework.

There are three dimensions to consider when estimating the impact of land-use change on nature: the **extent** of land use, the **condition** of the land used and the **significance** of the land (Figure 7).

Figure 7: Key components of land use impacts to calculate impact on nature



Key drivers of nature loss

The key drivers that lead to nature loss are: land- and sea-use change, direct resource exploitation, climate change, pollution and invasive species.[25] On a global scale, land-use change is the biggest and most direct driver of nature loss. CTI already addresses water use and GHG emissions. Future updates will include other key drivers to complement this indicator.

What it is (not)

This indicator measures land-use impacts associated with a company's material inflow, focused on measuring extent of land used, the intactness of the biodiversity on the land and the significance of land for biodiversity. This indicator can be used for technical materials and biological resources.

For simplicity and usability, the scope of this indicator is limited to the extraction and cultivation stage of sourced materials only. This stage has the most impactful land-use impacts. This indicator excludes land use of other stages along the value chain, such as processing manufacturing or distribution or recovery. It also excludes toxicity or other air, soil or water emissions that negatively impact nature.

EXAMPLE/S

Consider a company whose material inflow consist of aluminum to produce laptops. The company analyzes the land-use impacts of their inflow in 2022, producing 10 million laptops. The impact on nature will depend on how the aluminum is produced and from where the company sources it. For example:

- **Scenario A. Virgin materials:** The company produces laptops using virgin-sourced aluminum derived from bauxite. Bauxite is typically mined in large open pits, resulting in impacts on nature due to the transformation and occupation of land for mine shafts and storage of mine tailings. Moreover, these mines are often located in places that are globally significant for biodiversity (i.e., home to threatened species and high-integrity ecosystems) such as Brazil, Guinea or Australia.
- **Scenario B. Recycled material:** In contrast, if the company produces laptops using recycled aluminium, the recycling process entails a significantly lower change in the extent of land used since the material is an input in the recycling process.

SBTN & TNFD

Understanding and addressing land-use impacts is a priority for alignment with voluntary corporate biodiversity frameworks such as the **Science-based Targets for Nature by the Science Based Targets Network (SBTN)** and the **Taskforce on Nature-Related Financial Disclosures (TNFD)**. For example, SBTN has recently published draft guidance on developing science-based targets for metric can support companies to understand whether they have material impacts on land and conduct an initial materiality assessment for products and commodities.

The technical and biological recovery cycles

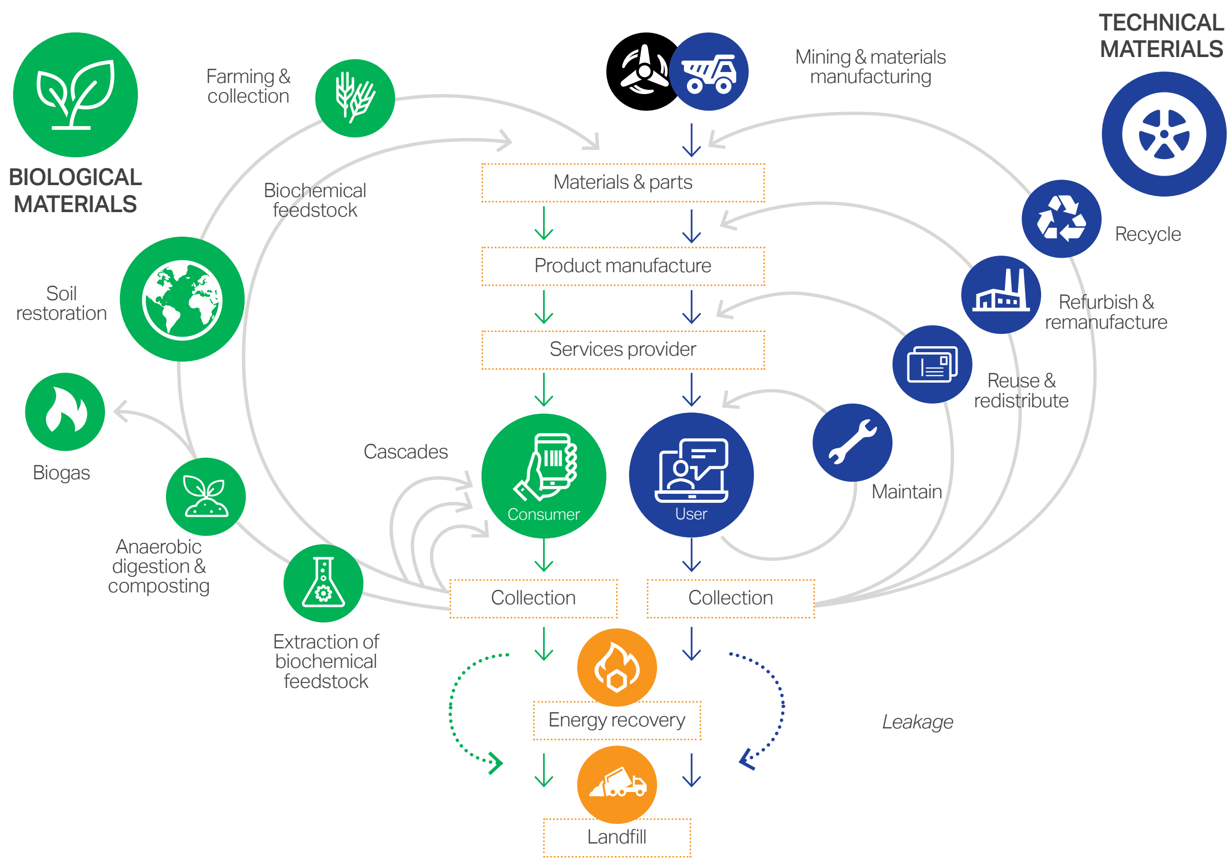
The circular economy recognizes two distinct sides, as shown in Figure 8. It is possible to recover technical materials through the technical cycle by means of different loops: maintenance and repair, reuse and redistribution, refurbishment and remanufacturing, and finally recycling.

Bio-based resources follow a different recovery path, as depicted on the left side of the graph. They circulate back into the biological cycle at their end of life for the reuse of their nutrients for a new cycle. It is important to note that bio-based resources are not unlimited in supply and need to originate from sustainably managed sources.

BIOLOGICAL CYCLE GUIDANCE

CTI offers extensive guidance on how to understand both biological and technical cycles and what that means for the circularity of the material flows.

Figure 8: Technical and biological recovery cycles



*Adapted from the Ellen MacArthur Foundation: https://www.ellenmacarthurfoundation.org

The classification of technical materials and biological resources

For optimal consistency between different circularity measurement frameworks, the classification of materials in either cycle draws from the Ellen MacArthur Foundation:

Materials suitable for the technical cycle

Those that companies can use, reuse/redistribute, maintain/prolong, refurbish/remanufacture or recycle. This includes all inorganic and fossil materials, such as metals, plastics and synthetic chemicals, as well as bio-based materials designed to be used within the technical cycle. Note that this category also includes materials of biological origin used as reactants in chemical processes and that form the basis of another material or product that behaves as a technical material.

Materials suitable for the biological cycle

Those that the company consumes or otherwise safely recovers into the biological cycle for conversion into nutrients, fibers or non-nutrient-rich materials in the next cycle.

The CTI process cycle

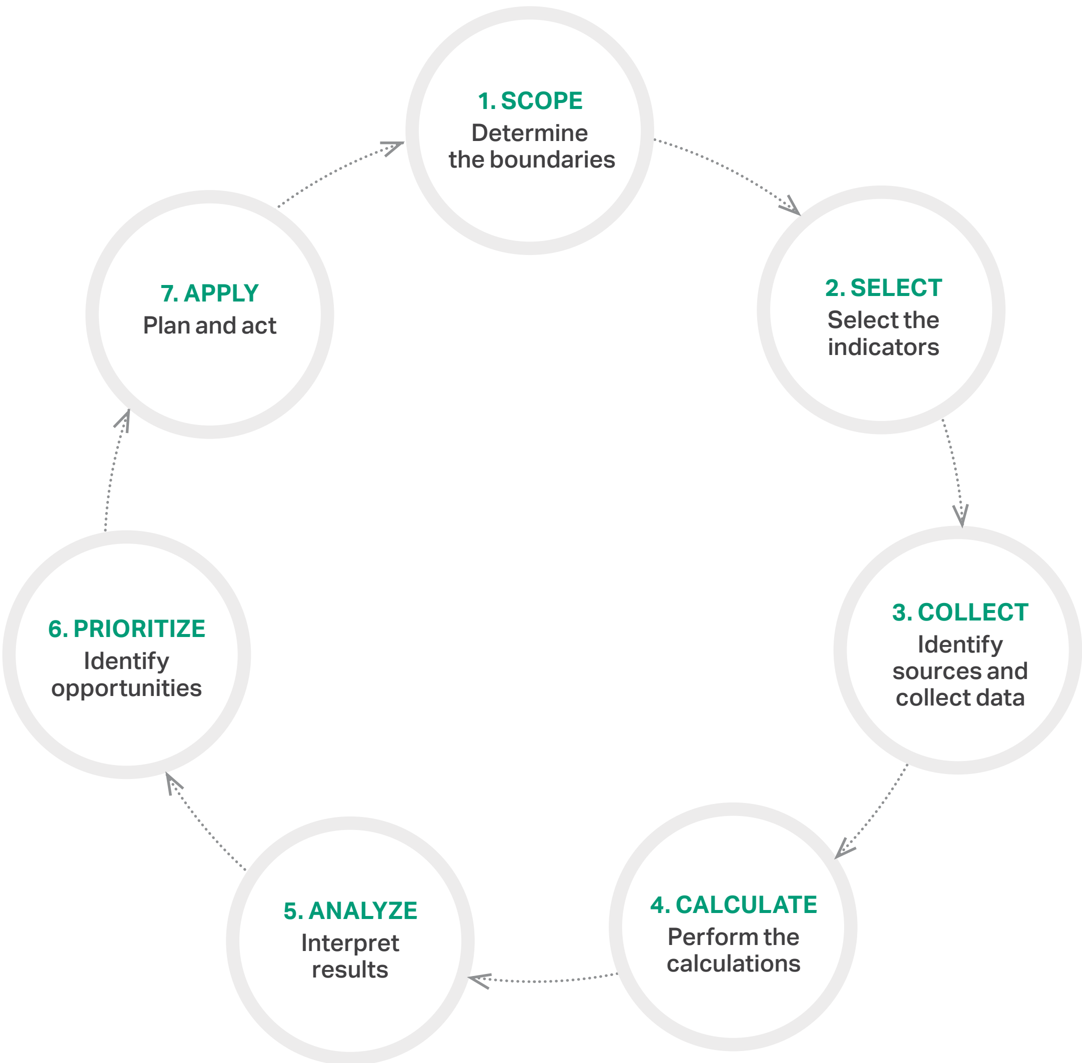
The framework outlines seven process steps that cover one assessment cycle. Running the assessment for the first time will be informative and insightful.

However, repeating the cycle regularly allows the company to monitor progress in its circular transition.

COMPATIBILITY

This process step approach is adapted from and consistent with other industry frameworks, like the Natural Capital Protocol.

Figure 9: The process cycle



Getting started

If you are interested in learning more and/or potentially using CTI and the online tool to start calculating your company's circularity, we have a few recommendations.

It may seem like a challenging exercise, but there are many free resources available to you to facilitate the process. We recommend the following:

1. Review the user manual for more instructions on how to find data, interpret outcomes and convert insights into action (see page 33).
2. Visit the CTI Academy at www.wbcsd.org/ctice to watch webinars, access case studies and sign up for upcoming events like training sessions and other learning opportunities.
3. Then sign up for your free Essential CTI Online Tool license at www.ctitool.com to help you start your assessment.
4. Start a simple and small scoped test assessment, something you may already have the data for.

KEEP IN TOUCH

These are the ways to stay informed or involved.

Stay informed
Regularly check www.wbcsd.org/ctice for updates on the framework.

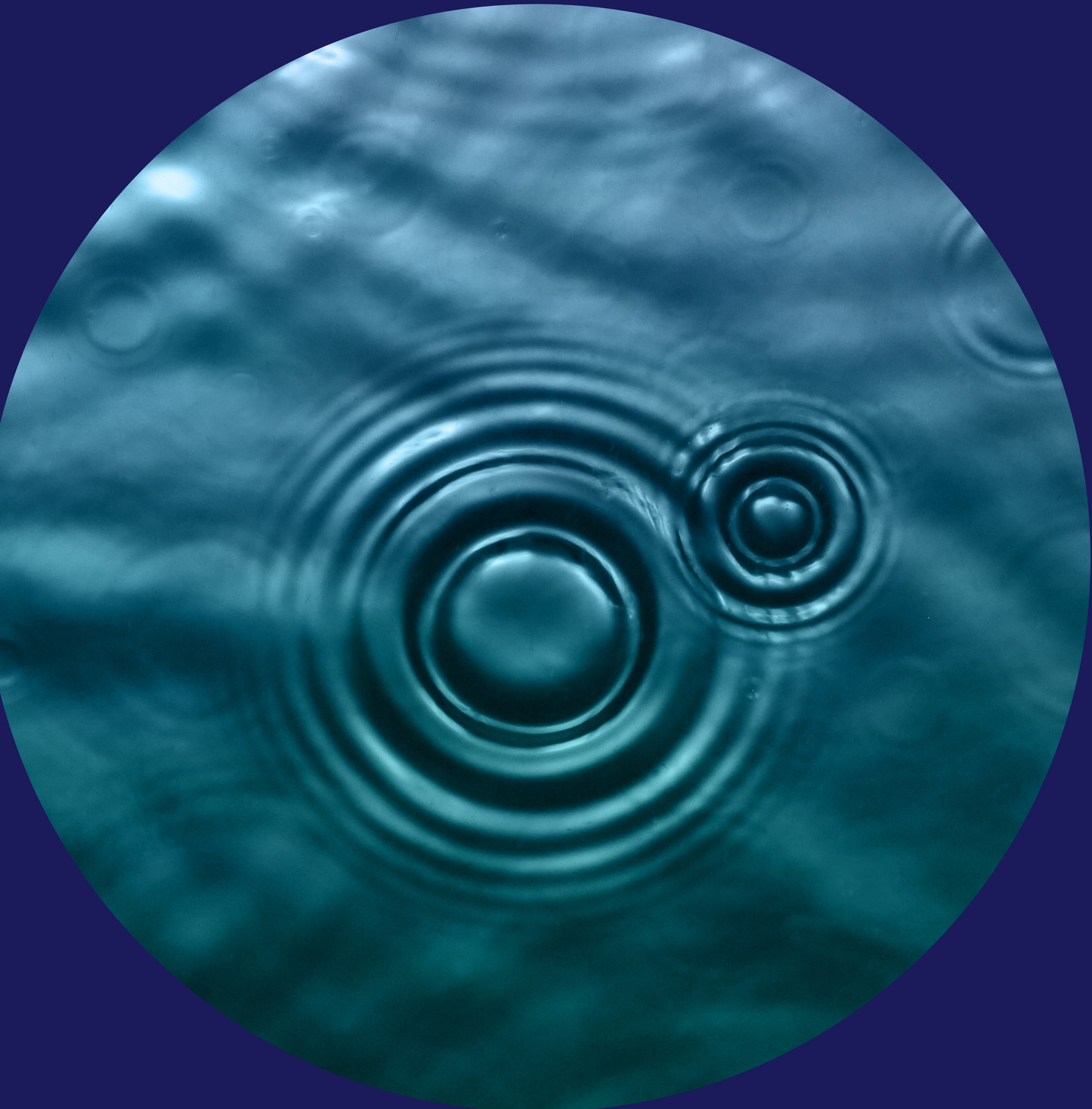
- Sign up for CTI circular and receive notifications on framework updates.
- Keep an eye on the events calendar for planned webinars and training opportunities and sign up.

Get involved
Share your insights and ideas through the feedback functionality in the CTI online tool www.ctitool.com

Actively help shape future CTI developments by joining WBCSD and the Circular Transition Indicators project.

Part 2.

Circular Transition Indicators: User manual V4.0



① Scope
Determine the boundaries

Before choosing indicators from the indicator menu, we recommend planning your circularity assessment to ensure you:

- Invest your time in finding the right data sets for the right reasons;
- Know what insights you are looking for in the outcome of the assessment;
- Have a plan for how you can take them forward.

Starting question: **What is the intent for the assessment?**
Consider the following questions in setting the objectives:

- Why is circularity important for the company?
- Which questions do we want to answer by doing this assessment?
- Who is the audience of the assessment's outcomes and insights? What do we want this audience to do with these insights and information? What other questions are they likely to ask after seeing the results?
- What business unit, product group or even specific materials should we focus on to start with? Where could impact drive optimal value for all stakeholders?

Stakeholder dialogue and collaboration here may be valuable. Once the objectives are set, use these questions to establish your scope:

1. **What level of the business do we assess?**
   You can assess the full company, but also specific parts of the company, such as a business unit, production facility or product line.
2. **What is the timeframe?**
   A yearly timeframe consistent with annual financial cycles will be a natural choice. However, it could be useful to use a production cycle or another more meaningful timeframe (such as one that is relevant to the construction sector or for capital equipment). Give this consideration some serious thought and choose something that complements the other scope parameters.
3. **What do we include and exclude?**
   For most companies, it will be extremely difficult to get all data on 100% of all material flows. This means that you might not include some flows in the assessment or that you may have to use proxies and assumptions. The company is free to set these proxies, assumptions and excluded streams, but must carefully document and fully disclose them if it intends to share the results.

QUESTIONS

- Where do I start and what are my opportunities?
- Which business unit is the most circular and how can we adopt cross-learnings?
- How do I assess whether my circular activities are good for my business?

AUDIENCE

Who do we want to talk to about this: the board, our employees, our suppliers, our clients? And what do we expect from them after we present our findings?

FOCUS MATERIALS

This mass-based methodology presents a risk of overlooking potential in material streams that are inherently light in weight (e.g., plastics and packaging). This is the moment where your team should determine any material streams you want to put extra focus on to ensure you capture opportunities.

EXCLUDED FLOWS

For manufacturing companies, the relative mass of operational materials (e.g., office supplies) as compared to production resources may be negligible. It could make sense for such a company to decide to not include such relatively small flows in the assessment.

2 Select
Select the indicators

Once your company understands its objectives, CTI offers a menu of indicators that enable the company to answer the questions from the scoping step.

Close the Loop

A company's ability to close material loops sits at the heart of the framework.

Consequently, companies start their assessment with these indicators:

- % circular inflow
- % circular outflow
- % water circularity
- % renewable energy

Optimize the Loop

These indicators illustrate how companies perform in lowering risks and maximizing high-value recovery beyond closing material loops.

The module includes two indicators:

- % critical materials
- % recovery type
  - % recovery by lifetime extension
- Onsite water circulation (facility reuse and recycle)
- Actual lifetime

Value the Loop

This module provides insights into the value the circular business creates.

It connects the material flow indicators with conventional financial metrics. Indicators included in this module are:

- Circular material productivity
- CTI revenue

While selecting your indicators, we recommend considering each indicator carefully and documenting why you have chosen to assess each one, as well as why you have excluded any.

QUESTION A

How can two business units learn from each other's circularity performance?

Running the assessment for both business units can help compare them and allow for the replication of best practices across units.

QUESTION B

How can we present the circular business performance to our CFO?

Circular material productivity can help determine the financial and economic performance of circular business, enabling communication with internal stakeholders.

QUESTION C

Which materials could provide a starting point for our circular procurement strategy?

% critical materials gives an indication of which materials the organization could prioritize to reduce its supply risks.

Impact of the Loop

This module illustrates the impact that circular strategies may have on a company's sustainability targets related to climate, nature and equity action.

- GHG impact
- Nature impact
    - Land use

While selecting indicators, we recommend considering each indicator carefully and documenting why you have chosen to assess each one, as well as why you have excluded any.

Land use is the biggest and most direct driver of nature loss.[26] Future updates will include other key drivers to capture the complexity of nature.

③ Collect
Identify sources and collect data

Data collection is likely to be the most labor-intensive part of the process. Some data points might be relatively easy to obtain, while others will require collaboration with other departments. It is likely that companies will have to connect with value chain partners to gather the relevant data, particularly on inflow and actual outflow recovery numbers. The following is the list of data sets required for each indicator module.

Close the Loop

% circular inflow (per material flow)

- % of renewable content or % non-virgin content per inflow type (see guidance on determination on page 44)
- Mass of each inflow type

% circular outflow (per material flow)

- % of the recovery potential per outflow type (see guidance on determination on page 46)
- Material recovery rates per outflow type:
  - Regional recovery rates
  - Sector-specific recovery rates
  - Material recovery rates from own buy-back/take-back contract, partnership system, collection and recovery programs, etc. (if applicable)
  - Mass of outflow per outflow type

% water circularity

- Volume, quality and source of water inflow
- Source vulnerability of water withdrawn
- Volume, quality and source of water outflow
- Local regulatory standard for discharge

% renewable energy

- Renewable energy used (annual consumption)
- Total energy used (annual consumption)

MFA

Performing a material flow analysis (MFA) could be helpful in preparing for a structured assessment. This would increase the robustness of the assessment and may be a good option for some companies. However, to optimize accessibility, we have not included it nor considered it necessary in the framework as a required process step. Results from existing MFAs could be valuable to start an assessment with.

ONLINE TOOL

The CTI online tool helps to collect data to minimize the burden of this step.

DOCUMENTATION

When collecting data, we recommend to documenting sources and provide justification. Uploading this documentation in the tool will help retrieve data in upcoming cycles and will enhance the robustness of the results and institutional memory.

Optimize the Loop

% critical flow

- A company's internal critical materials list;
- Existing public national or regional lists (e.g., European Commission 30 critical raw materials list or United States list of 35 critical minerals).[27]

% recovery type

Recovery type per recovered outflow. For example:

- Reused, repaired, refurbished, remanufactured, recycled for products moving in the technical cycle.
- Consumption by an organism, extraction of biochemical feedstock, biodegradation, biogas or biomass energy recovery under set conditions for products moving in the biological cycle.

Onsite water circulation

- Required water volumes per process in the facility.
- Required water quality level per process in the facility.

Actual lifetime

Companies should determine a reference lifetime value, for example lifetime (in time span OR number of use cycles) of prior product version or, if appropriate, an average of at least a few prior products; or the lifetime (in time span OR number of use cycles) of an "industry average" product, which is either:

- Calculated using a methodology consistent with both life-cycle analysis (LCA) best practices and with the methodology used elsewhere in the company's CTI response; or
- Obtained from reference literature, taking care to use the most up-to-date data and, at a minimum, not using data that is too outdated to reflect the current state of the industry.

DATA QUALITY

For CTI Tool users, the online The quality of insights gained from CTI depends on the quality of data entered. Data needs differ depending on the set scope and the selected indicators. The main types of data used in CTI are material inflows and outflows, which includes data on the end of life of the material streams. Data quality includes aspects covering data completeness, representativeness and precision.[28]

- **Completeness**
  All relevant indicators that meet the objective of the assessment are selected and all material inflows and outflow are included.
- **Representativeness**
  The data reflects the same time period and geography as determined in the scope.
- **Precision**
  The data needs to be as precise as possible, and uncertainties need to be reviewed and documented.

Value the Loop

Circular material productivity

- Revenue of assessed part of the business

CTI revenue

- Revenue per product (group)
- Level of circularity per product or product group (based on the Close the Loop indicators)

Impact of the Loop

GHG impact
Inflow

- All data points for the % circular inflow indicator
- CO_2-eq/kg sourced virgin materials
- CO_2-eq/kg secondary sourced (recycled) material

We recommend that the collection of information on the CO_2 equivalent for comparison between sourcing virgin and recycled versions comes from a credible secondary emissions factor database.

If your company has already collected supplier-specific information on the GHG footprint of both the virgin and secondary material sourcing options, you could use this information instead of collecting generic factors from secondary emissions factor databases. Pfrom secondary emissions factor databases. Please refer to Figure 10 for the boundaries of the comparison.

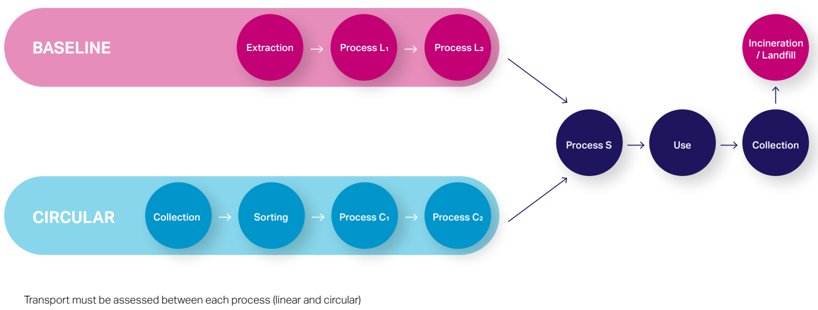
NOTE

For CTI Tool users, the online tool provides these values based on ecoinvent database v3.8 (cut-off version). In this case, the factors used are global averages based on a market approach where available. Factored into these values are the processes of virgin mining (linear), collection and recycling (circular) and transport. For an overview of all data points considered, refer to Figure 10.

You may also use other credible databases providing GHG emissions factors related to material production.

A list of recommended secondary emissions factor databases is available in WBCSD's Pathfinder Network guidance (page 31).

Figure 10: Setting the system boundaries of baseline and circular material flows



When collecting information on GHG emissions factors, companies should keep in mind that an exact specification of the material might not be available in existing databases. In that case, you may use the GHG emissions factors of a reference material instead.

Bio-based materials can be considered circular if they are renewable. A criterion of renewability is that the materials are sustainably grown. Research into the "sustainably managed" criterion did not provide supportive evidence of a lower GHG emissions burden compared to biobased material that is not sustainably managed. As a result, the material carbon footprint for renewable biobased material is not, by default, considered to be lower than the material carbon footprint of conventionally sourced biobased material.[29]

We recommend CTI users use their company's own emissions factors or supplier-specific information to determine the GHG footprint of the renewable biobased materials used.

Outflow

- All data points for the % circular outflow indicator
- CO_2-eq/kg preparation for reuse[30]
- CO_2-eq/kg recycling process[31]
- CO_2-eq/kg incineration (with/without energy recovery)
- CO_2-eq/kg landfill

To structure the data required for the different recovery strategies and support companies in data collection, we adopted the structure of the waste hierarchy (presented in the Waste Framework Directive). The waste hierarchy presents the following categories: preparation for reuse, recycling, energy recovery and landfill. Preparation for reuse activities clusters the reuse, remanufacturing, and refurbishing emissions.

We recommend that the information on the CO_2 equivalent for comparison between linear scenarios (incineration, landfill) and circular scenarios (preparation for reuse, recycling) originate from a credible secondary emissions factor database. If companies have already collected company-specific or third party-specific information on the GHG emissions impact of the presented circular recovery strategies and linear disposal strategies, they can use this information instead of collecting generic factors from secondary emissions factor databases. This provides the CTI user with the opportunity to use detailed GHG emissions impact data on the process under assessment and more precisely estimate savings.

The Waste Framework Directive **(Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives)** presents the basic waste management principles to be used in the EU. The directive presents the distinction between "waste" and "secondary materials" and a hierarchy to prioritize the preferred recovery options. The aim of the directive is to structure the recovery of emissions factors of different recovery strategies. It adopts no further definitions of "waste" or the "waste status". The hierarchy only provides a clear structure for different emissions factors associated with recovery strategies. (Waste Framework Directive (europa.eu))

Figure 11: Waste hierarchy

Source: European Commission Waste Framework Directive

Nature impact

The nature impact indicator requires an overview of incoming materials and products, a necessary step to calculate % circular inflow, measured in the Close the Loop module. It also requires additional data on land-use type, land-use intensity and sourcing location. This allows for the estimation of the extent, condition and significance (Figure 7) associated with a company's inflow. Scores can be summed across materials for a constituent product or entire value chain.

In general, each dimension requires the following primary data:

- Extent:
  - **All data points for the % circular inflow indicator**
- Condition:
  - **Type** (qualitative) based on the raw material type (e.g., natural forest, plantation forest, cropland, mine or industrial site)
  - **Intensity** (qualitative) based on the specific land use practices that are in place (e.g. conventional, organic, certified)
- Significance:
  - **Sourcing location** (e.g., country, sub-national region or precise location)

Companies can differ in their availability of primary data. Table 1 lists data availability scenarios varying from full primary data availability to limited data. The table recommends appropriate secondary datasets that can be used. Contextual datasets must complement all primary and secondary data.

Contextual datasets are data needed for interpretation, a company's own datasets can be used but the following ones are recommended:

- Extent:
  - **Yield per unit area estimates.**
    - Global and regional crop yields are freely available from FAO
    - Crop yields per country are freely available from OurWorldInData
    - Land use per unit of agricultural production per country is freely available from OurWorldInData
    - Global rock-to-metal ratios for inorganic materials estimated by Nassar et al. (2022).[32] Land required for the mine can then be estimated using simple mass to volume conversions and mine site geometry assumptions depending on the mine type. See Annex I for more details.

FLEXIBILITY IN CHOICE OF CONDITION & SIGNIFICANCE METRIC

We recommend using MSA to measure condition change and the STAR-t score to measure significance. Companies can use alternatives to these metrics, e.g., the Ecosystems Health Index or Ecosystems Integrity Index, to measure condition change. See Annex II: Choice of land use metrics for more information.

- Condition:
    - **Biodiversity loss coefficients**, based on Mean Species Abundance (MSA). MSA is based on the GLOBIO model[33] and allows for quantification of biodiversity loss relative to a pristine condition according to distinct categories of land-use types and intensities. We recommend adopting the biodiversity loss co-efficients outlined in Table 1 of the supplementary materials of the Natural Capital Impact Group's Biodiversity Impact Metric,[34] which is freely available.
- Significance:
    - **Extinction risk**, based on the Species Threat Abatement and Restoration (STAR) metric STAR-t score. STAR-t scores provide spatially-explicit quantitative estimates of the species extinction risk associated with a given area of interest. These data are not publicly available and can be accessed via the Integrated Biodiversity Assessment Tool Alliance (IBAT) platform or in the forthcoming country profiles in the WWF biodiversity risk filter.

Table 1: Definitions of data availability scenarios

Data scenario	Data source	Extent	Condition change	Significance
Limited data availability	Primary data available	Circular & linear inflow.	Company has no primary data on land use practices.	Company has no primary data on sourcing location.
	Secondary contextual data	Generic yield per unit area estimates (e.g., FAO) or rock-to-metal ratios (e.g. Nassar et al. 2022) to calculate extent.	Precautionary assumption: assume the most intense form of land use for the commodity and assign relevant biodiversity loss co-efficients.	Precautionary assumption: assume the commodity is sourced from the country with the highest Species Threat Abatement Restoration (STAR) metric score among the five market-leading countries (or fewer if they cover 80% or more of the market).
Moderate data availability	Primary data available	Circular & linear inflow specified per country origin.	Qualitative data on land use type and intensity.	National or sub-national sourcing information.
	Secondary contextual data	Country-specific yield per unit area estimates (e.g., OurWorldInData) or rock-to-metal ratios (e.g. Nassar et al. 2022) to calculate extent.	Biodiversity loss co-efficients per land use type and intensity.	Country or regional-level significance based on 80th percentile STAR score[35]
High data availability	Primary data available	Circular & linear inflow, site-specific information on origin, extent of land use known.	Detailed data onsite-specific land-use practices.	Exact coordinates of production site.
	Secondary contextual data	NA	Biodiversity loss co-efficient per land-use type and intensity.	Significance based on STAR score for 5 km x 5 km pixel of sourcing location.

Note: As per the primary data your company has available for each dimension and additional contextual data sets and assumptions that can be used according to the scenario

Data compilation process

1. List all raw material inflows for the selected scope used for calculation of % circular inflow and % material circularity. An additional step may be to convert the inflow from processed materials, parts, components or products into raw, unprocessed minerals or biomass for renewable materials. Conduct this step internally. However, where precise conversion is challenging, use approximate figures in line with the scoring card (see section: calculate).

2. Identify what material inflows are most impactful for nature. Check the list against the high priority commodity list provided in Table 2 or the SBTN High Risk Commodities List for initial prioritization screening (please find the latest version online). Note that the nature indicator can be used for both technical materials and biological resources. However, we propose this step to identify the materials that are likely to be most impactful for nature and thus simplify the process for companies with many different commodities and sourcing locations in their value chain.

3. Identify data availability based on definitions provided in Table 1 by asking the following questions:
    - Is the exact location of production (extraction, mining, cultivation, etc.) known?
    - Are the types of practices used for production known (e.g., organic vs industrial agriculture, strip vs open pit mining, any sustainability certifications)?
    - For inflow where detailed sourcing information is missing, is it possible to provide at least the country of production?

Table 2: Indicative, non-exhaustive, high-priority commodity list

Animal products	Crops (annual + plantation)	Mineral and fossil fuel commodities
• Cattle (beef, dairy, leather) • Fisheries • Pork • Poultry (chicken, eggs) • Sheep (lamb, mutton, wool)	• Cacao • Coffee • Cotton • Maize • Oil palm • Pulp and paper • Rice • Soy • Sugar • Rubber • Wheat	• Bauxite • Coal • Copper • Gold • Iron ore • Limestone • Oil + gas (inc. plastics) • Sand

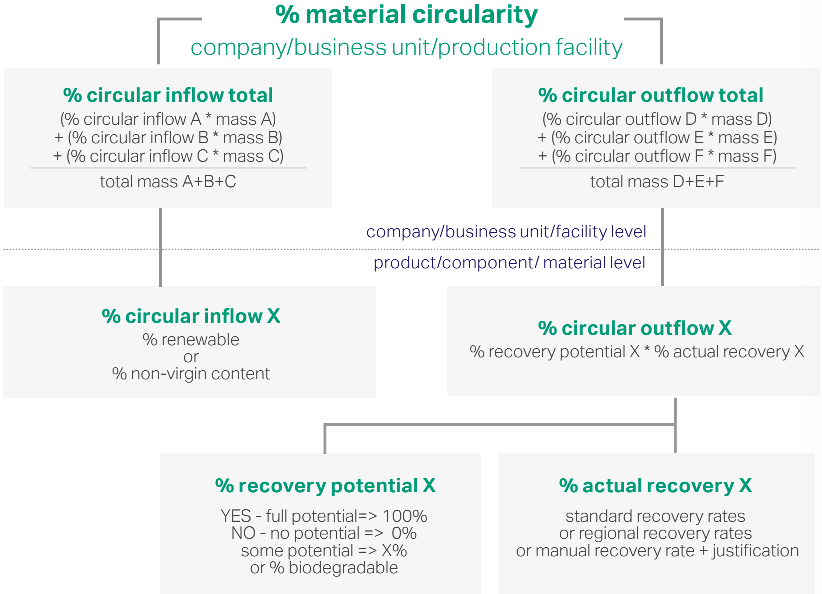
Note: We will replace this list with the SBTN High Impact Commodity List when released.

④ Calculate
Perform the calculations

CLOSE THE LOOP

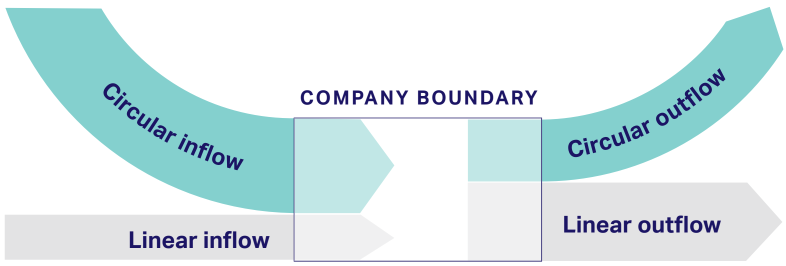
Figure 12 shows the high-level methodology to calculate % meterial circularity.

Figure 12: % material circularity



The percentage of material circularity – the weighted average between the % circular inflow and the % circular outflow – reflects the ability of a company to Close the Loop.

Figure 13: Four main material flows



Both the % circular inflow and the % circular outflow include the weighted average of the flows' % material circularity. Therefore, it is necessary to assess the % material circularity at a flow level.

ASSESSMENT LEVEL

CTI can assess the full company, as well as specific parts of the company, such as a business unit or production facility.

WEIGHTED AVERAGE

The percentage of material circularity is based on the average of the weight-based circular inflow and circular outflow divided by the total inflow and outflow. In most cases, this will be around 50%/50% but in specific cases (e.g., high stock) it is necessary to correct that difference by taking the weighted average.

MATERIAL FLOWS

Material flow can include nutrients, compounds, materials, parts, components or even products (depending on the organization).

WATER

Water is a unique resource companies use for different purposes. Due to its weight and the quantities companies use, water may distort the outcome of the assessment. Water is therefore not part of overall % circularity. Rather, it has its own indicator.

Figure 14: % material circularity formula

% material circularity
company/business unit/production facility

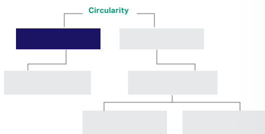
% circular inflow total	**% circular outflow total**
(% circular inflow A * mass A) + (% circular inflow B * mass B) + (% circular inflow C * mass C) ――――――――――― total mass A+B+C	(% circular outflow D * mass D) + (% circular outflow E * mass E) + (% circular outflow F * mass F) ――――――――――― total mass D+E+F

% Circular inflow

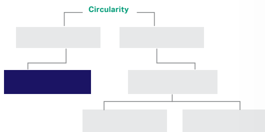
This indicator assesses the total circularity of inflowing materials:

% circular inflow total

(% circular inflow A * mass A)
+ (% circular inflow B * mass B)
+ (% circular inflow C * mass C)
total mass of all inflow (A+B+C)



This means that **% circular** inflow needs to be determined on a material level



GUIDANCE FOR THE TECHNICAL CYCLE

Technical inflow can be either

- **Virgin/primary: linear**

These materials have not been used before. For these materials:

% circular inflow V = 0%

- **Non virgin/secondary: circular**

These materials have been (partially) used in a previous cycle (for example reuse, remanufacturing, recycling). For these materials

% circular inflow NV = % recovered content

For the % circular inflow it makes no difference whether a material is considered circular because it is renewable or non-virgin. Both classifications count as equally circular.

In some cases, inflow can be both renewable and non-virgin. In such cases, only count the inflow in one of the circular categories to prevent double counting.

CLASSIFICATION

Depending on the company and its position in the value chain, it may be challenging to determine the amount of each of the three streams. The most important distinction here is to separate circular from linear flows.

WASTE MANAGEMENT

It may not be possible to identify whether waste streams that flow into the company are renewable or secondary.

Inherently this incoming waste is not virgin; therefore, in this case, companies can count this material as non-virgin or secondary. As long as you account for any additional flows (like process materials), you can consider the rest of the total as circular.

MATERIAL PRODUCTION

On the other end of the value chain, for material producers it can be much easier to identify virgin renewable and secondary inflows. In this case companies can account for all remaining inflows as linear.

GUIDANCE FOR THE BIOLOGICAL CYCLE

Bio-based inflow can be either

- **Renewable: circular**

Companies can consider bio-based inflow as circular if it is sustainably grown and replenished or regrown through natural cycles after extraction. It is preferably regenerative and at a minimum sustainably managed. (See the glossary on page 105 for complete definitions and references.)

Inflow may consist of fully or partially renewable content. In this case:

% circular inflow R = % Renewable content

- **Non-renewable: linear**

CTI does not consider unsustainably managed bio-based resources as renewable; therefore they are not circular. For these resources:

% circular inflow NR = 0%

CIRCULAR ECONOMY, REGENERATIVE OR SUSTAINABLE?

The circular economy is a full restorative model in which ecosystems are relieved of their current pressure and managed to have a chance to restore and become self-regenerative systems. As a result, they will automatically produce sustainable resources.

The renewable inflow in CTI, for now, focuses on preferably regenerative but at least sustainably managed resources.

For companies that have the ambition to go beyond sustainability and want to measure their regenerative performance in restoring ecosystem health, WBCSD is considering developing an additional indicator set.

If you are interested in participating in this development, please contact CTI@wbcsd.org

Alternative calculation method % circular inflow

In addition to the bottom-up calculation of % circular inflow, CTI offers a top-down calculation for the % circular inflow, which may be easier for some companies to use:

% circular inflow

$$\frac{\text{mass of renewable inflow} + \text{mass of non-virgin inflow}}{\text{total mass of all inflow}} \times 100\%$$

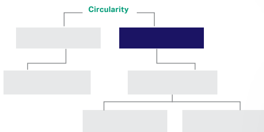
The required data set is the same and the outcome of the two approaches should be the same as well.

% circular outflow

Like total % circular inflow, this formula assesses the total circularity of outflowing products, by-products and waste streams:

% circular outflow total

$$\frac{(\text{\% circular outflow D} * \text{mass D}) + (\text{\% circular outflow E} * \text{mass E}) + (\text{\% circular outflow F} * \text{mass F})}{\text{total mass of all outflow (D+E+F)}}$$



This means that the % circular outflow needs to be determined per type of outflow.

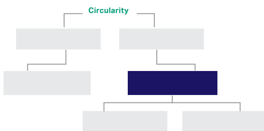
% circular outflow reflects the combined effectiveness of your company to:

1. Design or treat its outflow to be recoverable. For example, the outflow should be repairable, refurbishable, manufacturable or recyclable for the technical cycle and biodegradable for the biological cycle. This is the % recovery potential.

2. Demonstrate that the economy or biological cycle recovers products, by-products and waste streams that leave the company. This is the % actual recovery.

% circular outflow X

% recovery potential X * % actual recovery X



If the materials are neither treated in such a way that they have any technical recovery potential, nor able to be reintroduced into the value chain or biological cycle, consider the outflow as linear.

DOUBLE COUNTING

Companies should account once for inflow that is both renewable and non-virgin. It is up to the company to select which one the material should qualify for.

OUTFLOW INCLUDED

Flows to consider as outflow include sold product (including packaging), by-product and waste, either in solid, liquid or evaporated form. This can include process or operational by-product or waste.

HIGH POTENTIAL, LOW ACTUAL RECOVERY

Old information and telecommunication equipment can often be partially dismantled, meaning it can have high recovery potential.

However, its incineration (either with or without energy recovery) destroys the materials. They lose their value and potential for reuse, refurbishment or recycling and will therefore score 0% in actual recovery, resulting in 0% circular outflow.

% recovery potential

The % recovery potential reflects the ability of the company to design its outflow to ensure it is technically recoverable through either the technical or biological cycles.

For most flows, the typical categorization is:

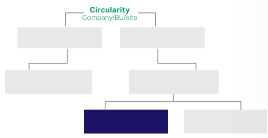
YES, this outflow is fully recoverable – resulting in 100% recovery potential.

Or

NO, this outflow is not recoverable – resulting in 0% recovery potential.

% recovery potential X

YES - full potential= 100%
NO - no potential = 0%
some potential = X%
or % biodegradable



Guidance for the technological cycle

For technical outflow that can consist of (by-)products or waste, the company must determine the recovery potential. Should you require support in determining this for your company, please contact us for additional guidance.

As new technologies develop, drawing the line between circular and linear for the recovery potential becomes more difficult. Since debates are raging worldwide on what qualifies as circular for processes such as chemical recycling, this framework does not offer a universal answer. As a temporary guiding principle: if a technical material on any level (potentially molecular) can remain a functional equivalent material in a second life in a technically feasible and economically viable manner, it is circular. If the company downcycles inorganic or fossil material or turns it into a fuel or burns it in any shape or form, it is linear.

PANELS

Construction panels produced by glueing metal and plastic sheets together will have no recovery potential as, after the product's technical lifetime, it is not possible to separate and recover these materials. The recovery potential is 0%.

In comparison, panels connected with screws or rivets can have 100% potential, since it is possible to separate and recover both materials (depending on the individual material characteristics). The screws or rivets may even be reusable or recyclable.

PAPER

Natural paper can be 100% recovered through the biosphere.

However, contamination by bleaching, dying, printing or coating with inorganic substances can disturb its biodegradability, making it unrecoverable, and could therefore cause it to have 0% recovery potential.

Guidance for the biological cycle

What does recovery potential mean for resources that are suitable for absorption in the biosphere? Two criteria – biodegradability and toxicity – determine this.

Biodegradability

To what extent can the product or material flow biologically decompose?

The % recovery potential is the weighted average of the % biodegradability of its components or compounds, under the condition that it is possible for the consumer to separate bio-based resources from technical components at end of life. Consider so-called hybrids designed in a way that intertwines technical and bio-based materials and the consumer cannot separate them (for example a garment with both cotton and synthetic yarns or shower scrubs containing microplastics) to have a 0% recovery potential.

The Organisation for Economic Co-operation and Development (OECD) biodegradability testing standard describes biodegradability and other International Standards Organization (ISO) and Royal Netherlands Standards Institute (NEN) norms are also available for reference (e.g., compostability).

Companies may freely choose their standard of preference based on what best represents their business needs.

Toxicity

Is the product or material flow (solid, liquid or evaporated) free from harmful substances to the biological cycle?

Only consider a product to have recovery potential if its levels of toxins or hazardous substances fall within predetermined thresholds.

For the purpose of consistency across the metrics landscape for the circular economy, CTI refers to the Cradle to Cradle Certified Products Program, DRAFT v4 Restricted Substances List (RSL).

The RSL includes acceptance thresholds for all identified substances and it can be used to check the acceptance levels of harmful substances in your biodegradable outflow.

FOOD WASTE

By default, consider food waste as biodegradable. If local authorities (e.g., U.S. Food and Drug Administration) clear it for human or animal consumption, you can safely consider **recovery potential** to be 100%.

For food, the focus within CTI will be on whether that food is in fact used for its purpose (consumed and so providing its nutrients to other life forms in the biosphere or repurposed) or whether it is wasted or lost.

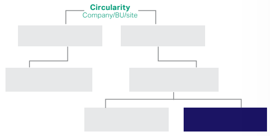
Therefore the % **actual recovery** will be the key indicator to determine success in closing the loop on food products.

% actual recovery

The % actual recovery indicator captures the amount of outflow recovered at the end of its initial life cycle.

% actual recovery X

standard recovery rates
or regional/sector recovery rates
or manual recovery rate + justification



Recovery is not the same as collection. After collection, materials can still end up in landfill or incinerated. Therefore, this indicator is not based on estimates but requires actual data. If your company keeps control and tracks its product flows after they leave your facility, this data should be available. For transparency and robustness, when using internal recovery data for the calculation, we recommend to secure the appropriate supporting documentation.

In case your company does not keep track of its outflows, it can refer to standard (often national or regional) recovery rates available for a wide range of product groups (for example specific electronic equipment, food, textiles, etc.).

Guidance for the technological cycle

Recovery data for many technical materials is dependent on region or sector. For an accurate view, we recommend considering default rates for the product/material based on the geographic scope of sales/use and/or sector-specific data, where available. Recovery for technical materials includes only material recovery, not energy recovery.

In step 1, companies establish a timeframe for their CTI assessment, usually one year. Recognizing that many products go into products and use stages that last over a year, companies should use the actual recovery rates for that year in their calculations.

As recovery rates generally improve over time due to regulations, taking the current recovery rates serves as a worst-case scenario assumption for the actual recovery of those products, components and materials.

If a product is going into stock for years or decades, the focus of CTIshould be on circular inflow and recovery potential to ensure that all possible measures for the company to take today are in place.

FASHION

Some clothing brands collect old garments with the ambition to recycle them. This framework only considers the actual fabric and fibers that find their way back into another used garment, accessory, household cloth, etc. as recovered.

SELLING LIGHT

In addition to buying lightbulbs, it is now possible to solely buy light. In a maintenance contract, the lighting company retains ownership of the light fixtures, allowing it to maintain control of outflow and data on repaired and reused material and making it available internally.

T-SHIRT

When a biodegradable product (like a cotton t-shirt with no toxic dyes) ends in a landfill, the toxic mix of combined waste contaminates it and it can no longer serve as nutrients in the biosphere. Although it had a recovery potential of 100%, it is considered linear outflow.

Guidance for the biological cycle

Like the technical cycle, CTI proposes different loops in which the biological cycle can absorb biological resources. The Optimize the Loop section outlines this further.

Consider a product or material flow as actually recovered in the biological cycle only if it biodegrades as intended during design (e.g., composting).

Biofuel and energy recovery from biomass

One important difference with the technical cycle is that bio-based resources can, through the process of combustion that may occur in nature (e.g., fire caused by lightning), return to the biological cycle. However, the conditions in which this occurs can only be considered circular for CTI under specific criteria drawn from the Ellen MacArthur Foundation Material Circularity Indicator framework:

1. Other end-of-life options, besides landfill, must have been exhausted (in terms of technical capability and economic viability).
2. The material must be from a biological source.
3. The biological material must be demonstrably from a source of sustained production (i.e., regeneratively produced).
4. The biological material must be uncontaminated by technical materials – except where these are demonstrably inert and non-toxic.
5. Energy recovery must be optimized and the energy usefully employed to displace non-renewable alternatives.
6. The by-products of the energy recovery must themselves be biologically beneficial and must not be detrimental to the ecosystems to which they are introduced.

Consider landfill and incineration in mixed waste as linear. Even though 50% may still consist of biological matter, it does not follow the above-mentioned criteria for classification as circular. In cases where no data is available for a flow AND there is no downstream tracking, consider the actual recovery as 0%.

The challenge in monitoring flows, particularly multiple steps up or down the value chain, is recognized. Only through value chain collaboration is it possible to effectively communicate the importance of collecting and sharing this data. The hope is that the CTI provides a consistent process and reason to initiate these discussions if they have not started already.

FOOD WASTE

Except for food and feed, consider most biological resources as circular as long as their nutrients return safely to the biological cycle.

The purpose of food is to nurture human beings and animals and simply returning it to the biological cycle is insufficient for classification as circular. Therefore, consider only consumed food as 100% recovered (circular).

Consider the valorization of food waste through biodegradability or biofuels/biogas as only 50% circular.

Consider landfill and incineration of food waste (with and without energy recovery) as linear.

Cascading

Recovery goes beyond giving a material a second life. The current criterion for technical circular flows is that the material can technically achieve a functional equivalence state of inflow at which it entered the company (whether it is a material, part, product, etc.). This same functional equivalence means that the company or other companies can use it for the same or similar purpose.

Technical flows turned into energy through incineration are not circular in this framework as they do not return at the same functional equivalence after incineration.

PLASTIC

If a high-grade plastic in small IT equipment is not reusable in the same product but is reusable in the body of a coffee machine and can loop multiple times as recycled content, it is circular since this is functionally equivalent.

RUBBER

Consider ground-up tires used in playground floor tiles as circular when, after their life as playground flooring, they could be used again, either as new playground flooring or something else.

CO-PROCESSING

Co-processing refers to the simultaneous use of residual waste as a source of mineral resources (material recycling) and as a source of energy to substitute fossil fuels in a single industrial process. In this case, the residual waste would qualify as circular inflow but the only portion of the outflow that would be circular is the residual fully recovered and used in another process while maintaining functional equivalence. Consider the rest of the outflow as linear as it is a technical cycle or a mixed waste stream that is incinerated, prohibiting its reuse.

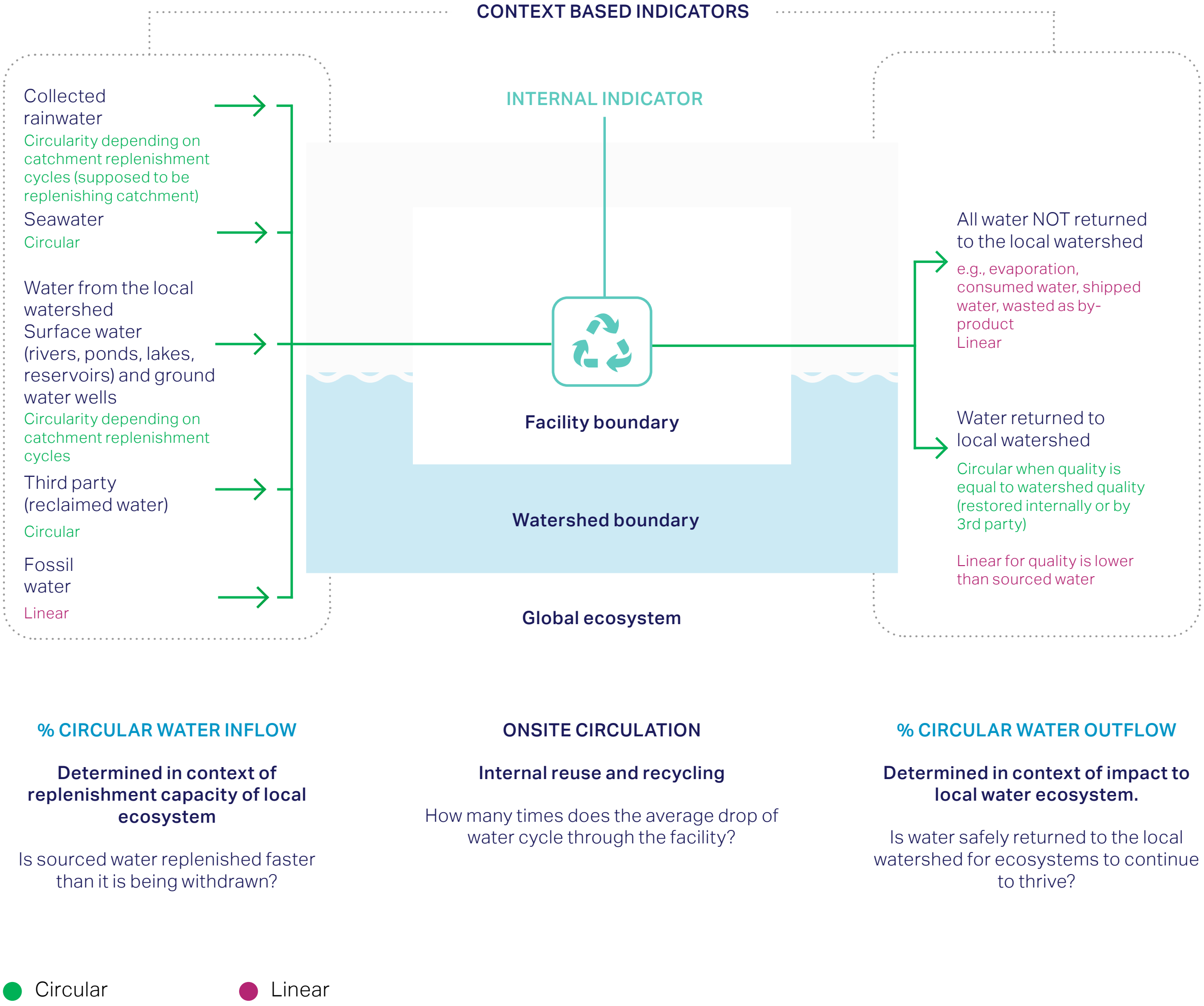
% water circularity

Freshwater is a finite yet vital resource. It is critical to use it responsibly and to apply circular principles where possible.

What sets water apart from other materials and resources is the scale of the relevant ecosystem. Where materials can circulate in a global system, it is necessary to assess water circularity on a local level for a water catchment area or local watershed. This will determine the actual availability of water for the company facility and all surrounding stakeholders depending on water supply in the water catchment. The purpose of water circularity is to lower freshwater demand and ensure water resource availability for all.

In Figure 15 below, note how the company (facility) boundary resides within the watershed boundary.

Figure 15: Water system diagram



Basic principle for water circularity

To assess water circularity, CTI offers two **context-based indicators and one internal indicator.** While the context-based indicators are necessary, the internal indicator is optional. The two types of indicators are based on the same data set.

Context-based water indicators

The water circularity of a product facility or the location of the company is the average between % circular water inflow and % circular water outflow (assuming the volume is the same).

% water circularity
production facility or location

% circular water inflow | **% circular water outflow**

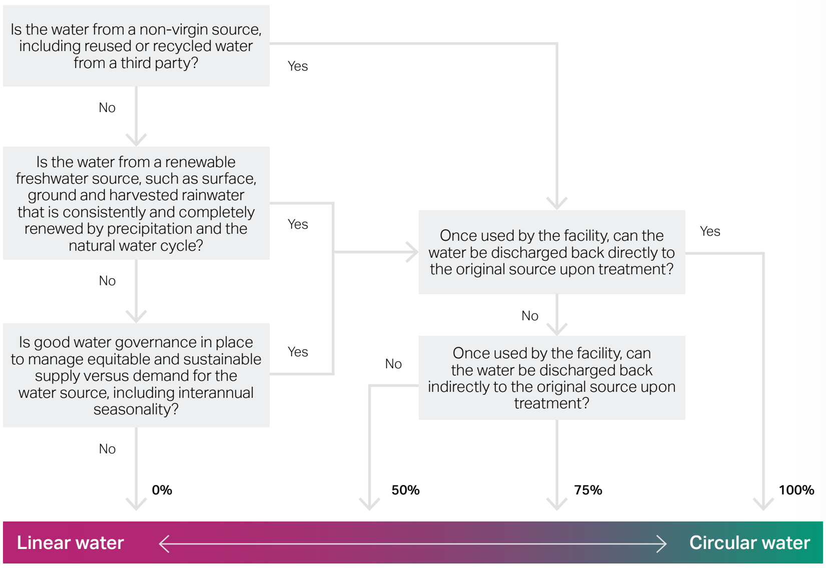
% circular water inflow

This indicator determines the total circularity of all water inflow over the chosen timeframe. Its calculation is as follows:

% circular water inflow

$$\frac{\text{Q total circular water withdrawal}}{\text{Q total water withdrawal}} \times 100\%$$

Determine the circularity of water inflow by using the following decision tree:



% circular water outflow

This indicator determines the total circularity of all water outflow over the chosen timeframe. Its calculation is as follows:

% circular water outflow (restored)

$$\frac{\text{Q total circular discharge}}{\text{Q total water withdrawal}} \times 100\%$$

Following the basic principle for water circularity, circular outflow has three criteria:

1. Water outflow is circular if it is recycled (offsite) by other sites, this includes drinking water supply to communities within the basin.

2. Discharged water is circular if it returns to the local watershed at a quality that makes it readily available for environmental, social, agricultural or industrial purposes.

3. Product water is circular if returned to the local watershed to a quality that makes it readily available for environmental, social, agricultural or industrial purposes.

CIRCULAR WATER INFLOW DECISION TREE

The decision tree can help to define whether the source of inflow is circular or linear. Ultimately, it aims to drive decision-making towards more circular inflow options. In using the decision tree, it is important to have access to credible local data on freshwater sources.

WATER QUALITY

Water quality is a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics. Different water uses, such as drinking water, irrigation or industrial processes, will have specific quality thresholds or parameters as determined by an appropriate authority (e.g., government ministry) and/or industry standards.

HUMAN-MANAGED VERSUS NATURE-MANAGED WATER

In a rudimentary way, it is possible to divide the water cycle into what nature manages and what humans manage. Within a given basin, the natural water cycle acts to reoptimize, reuse and replenish water. On the human-managed side, human actions impact water's circularity when we alter the natural water cycle through withdrawal, use and replenishment.

For more guidance on WBCSD's circular water metrics, consult the water metric guidance and tool.

The facility itself or a third party can do the necessary water treatment before discharge.

Facility internal indicators

Onsite water circulation

This indicator expresses the number of times the company uses the average drop of water onsite before it leaves the facility as outflow.

The calculation is as follows:

Onsite water circulation (reuse & recycle)

$$= \frac{Q\ \text{water use} - Q\ \text{total water withdrawal}}{Q\ \text{total water withdrawal}} + 1$$

The total quantity of water used by the facility is the sum of all water required by all its processes (e.g., washing, cooling, ingredient water, tap water, etc.).

Energy and nutrient recovery

It may be possible to recover energy and/or nutrients from water before discharging it. CTI recognizes this as circular practice; however, the water circularity indicator does not include it. Both types of recovery can contribute to either % renewable energy or % circular outflow. Process the absolute values of either data set in these chapters.

WATER CIRCULARITY, WATER STEWARDSHIP AND SUSTAINABILITY

Several approaches and initiatives aim to measure different aspects and impacts of water management: sustainability, stewardship and circularity. It is important to frame these aspects as not the same yet related.

For example, circularity can help realize water stewardship goals, which in turn can lead to more sustainable water use; but circularity is not equal to sustainable water use. Other methodologies – current or under development – aim to measure these aspects.

For sustainability, the Science Based Targets Network is developing guidance to apply science-based targets for nature, including freshwater. And for water stewardship, WRI and others have published a method for implementing and valuing water stewardship activities: Volumetric Water Benefit.

% renewable energy

In a circular economy, energy production depends on renewable sources and shifts away from fossil fuels.

Because of the complexity involved in calculating it and the potential to cloud the results, CTI measures renewable energy used for business operations separately.

The formula for the % renewable energy is:

% renewable energy

$$\frac{\text{renewable energy (annual consumption)}}{\text{total energy (annual consumption)}} \times 100\%$$

Most companies already use globally recognized and generally adopted protocols for measuring and reporting renewable energy consumption.

In line with WBCSD's approach, CTI allows companies to use existing policies and procedures, permitting the reuse of existing data sets.

Should you need guidance on the definition of renewable energy, please refer to the energy sources published by IRENA (International Renewable Energy Agency).[36]

- Solar energy
- Wind energy
- Hydropower energy
- Geothermal energy
- Ocean (tidal) energy
  Bioenergy

Measurement expresses the energy content and includes all the energy carriers that flow into the company (including, but not limited to, gas, electricity and fuels).

For the purposes of CTI, it is not possible for a company to achieve greater than 100% renewable energy in this indicator. Consequently, even if a company generates more renewable energy onsite than it uses and sells it back to the grid (utility), it's necessary to cap the renewable energy indicator at 100%. The intent here is to maintain a relatively simple focus on encouraging the shift to renewable energy consumption.

MATERIAL FLOWS AND ENERGY GENERATION

Classify inflow for energy generation as circular inflow if it is renewable or non-virgin.

Always classify outflow that is either used as fuel and/or incinerated as linear.

ENERGY CARRIERS

If the energy carriers enter the company as a physical material flow, consider them within the inflow calculation of the company. If these are non-virgin or renewable, consider them as circular inflow. Alternatively, consider any energy entering the company as energy content (i.e., electricity for processes delivered by the grid) within the % renewable energy calculation.

OPTIMIZE THE LOOP

Critical materials

This indicator provides a first impression of the percentage of inflow at risk by making an initial distinction between critical and non-critical materials.

The first step is to identify, within the inflow, what mass of the total inflow is critical. Critical materials are prone to becoming scarce in the relatively near future and are difficult to substitute without hampering functionality. Several institutions have identified critical raw materials. For example, the European Union (EU) lists 30 raw materials as critical.[37] In addition, the United States has developed a list of 50 mineral commodities deemed critical to US national security and the economy.[38]

These lists do not include criteria on problematic supply chains, such as from human rights violations perspectives. Time may see the addition of other sources, including human and environmental capital-related supply chain issues.

Other authorities may be developing or have already published comparable lists of critical or scarce materials. Although regional lists can deviate, materials that appear on any list warrant a second look.

% critical material

$$\frac{\text{mass of inflow defined as critical}}{\text{total mass of linear inflow}} \times 100\%$$

CRITICAL MATERIALS

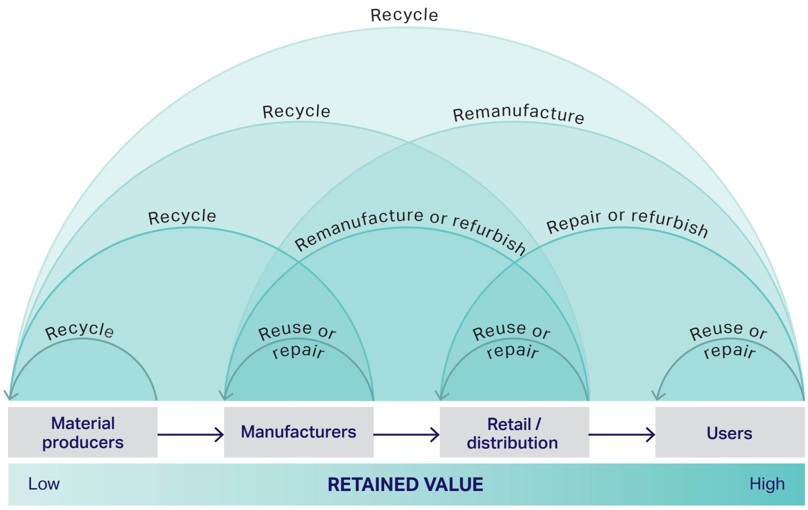
Obtaining this information may be challenging for industries with high product complexity (e.g., in the electronics sector). Additionally, critical materials might exist in very low quantities in components that travel through the value chain.

The company can decide whether to assess the exposed risk associated with a dependency on any of these materials. Efforts to gain supply chain transparency at this level could be significant. On the other hand, the risks involved could be worth looking into.

Recovery type

Within the Close the Loop module and the % material circularity, the scoring for the recovery types for flows moving in the technical cycle is not different when excluding downcycling and energy recovery. This position is necessary as each strategy may need to take place at some time at some place in the value chain.

Figure 16: Retained value



For example, it is not possible to recover a product endlessly and at some point it might require the recycling of its materials. For the Optimize the Loop module the % recovery type provides a deep exploration of higher value retention strategies within company reach. As illustrated in Figure 16, tighter recovery loops typically require less energy or processing and are more efficient forms of material/product recovery providing more retained value. For example, repairing instead of recycling a product requires fewer logistics and less reproduction and retains more product value.

Generally, it is in the best interest of a business to explore opportunities to keep recovery loops as tight as possible.

The CTI online tool includes optional data entry at the outflow level, specifying the type of recovery used for recovered products, by-products, waste streams, etc. The feedback provides a breakdown of the shares of recovered material reused/repaired, refurbished, remanufactured, recycled or biodegraded.

ALL LOOPS ARE EQUALLY CIRCULAR

Although tighter loops are generally preferable, all types of recovery are equally circular in CTI.

As such, all recovery types contribute to a company's circularity performance equally in the Close the Loop calculations. This means that a shift in recovery type will not change the % circular outflow. The recovery type indicator would, however, capture this.

Recovery type: % recovery by lifetime extension

In a circular economy, the most effective way to retain the value of resources is by keeping products, components and materials in use for as long as useful. Companies can achieve this by incentivizing the uptake of lifetime extension strategies (reuse, refurbish, remanufacture) whenever these are available.

For companies wishing to track their performance across strategies that retain higher value in the technical cycle, CTI v3.0 provides a separate score: % recovery by lifetime extension. This score compiles a separate performance score for those outflows that are reused, refurbished or remanufactured. The online tool provides this score automatically based on data entry at the outflow level for the % recovery type indicator. The indicator applies to actual recovery types for technical materials and for bio-based materials that behave like technical materials (e.g., wood).

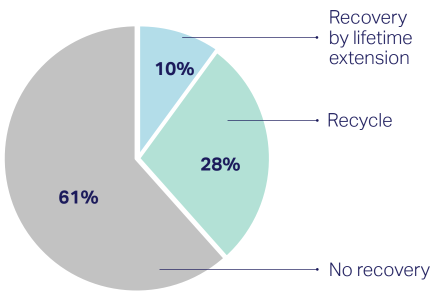
Table 3: Recovery by lifetime extension strategies

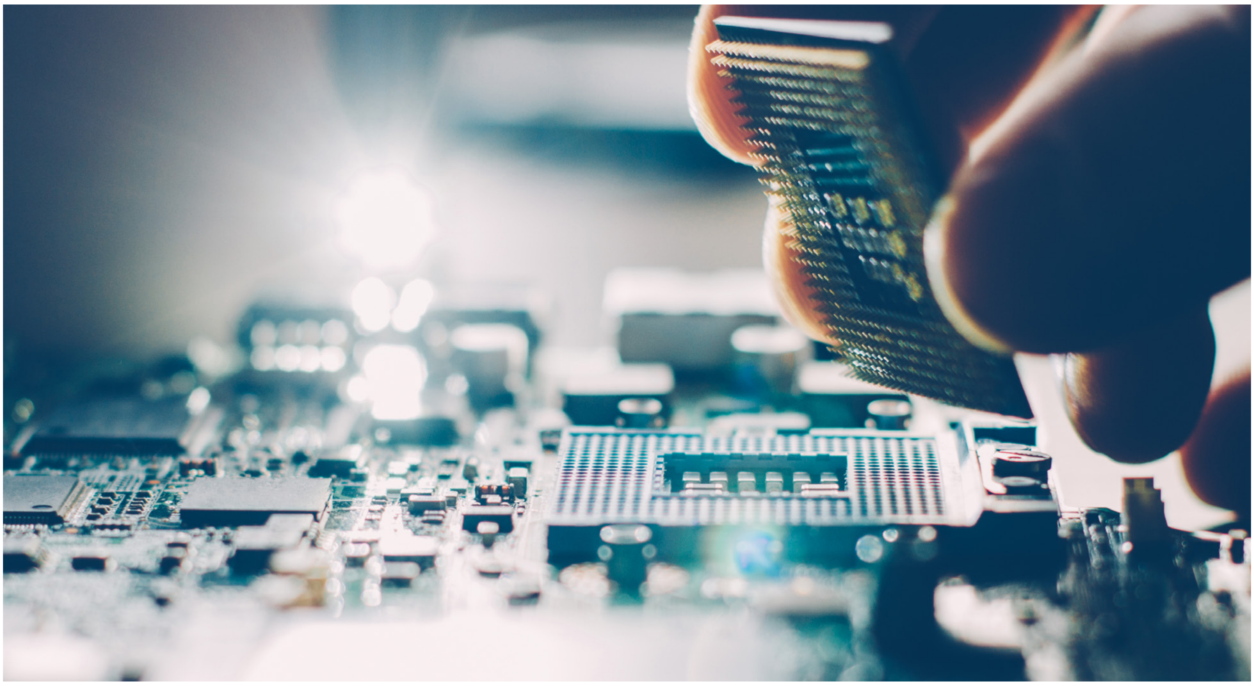
		Type of recovery	Description	
CIRCULAR	LIFETIME EXTENSION	% reuse	No changes made except for cleaning and minor repairs, same functionality	% recovery by lifetime extension
		% refurbishing	Changes made in the form of refurbishment or large repair, components or parts might be replaced, same functionality	
		% remanufacturing	Changes made, components or parts are replaced or used elsewhere, different functionality	
		% recycling	Mechanical or chemical recycling of the materials	

You must take outflows that are considered waste during lifetime extension activities into account as either recycled or not recovered. While recycling is a recovery type and considered circular in CTI, it does not lead to lifetime extension and therefore this sub-indicator excludes all mass flows recycled in the next cycle.

Figure 17: Example of recovery types breakdown for a washing machine - % recovery by lifetime extension

		Recovery type – breakdown	**35 kg**
CIRCULAR	**LT EXTENSION**	Re-use	0kg
		Refurbish	1kg
		Remanufacture	2.5kg
		Recycle	10kg
LINEAR		Landfill / mixed waste incineration	21.5kg
		Unknown / Other	0kg





Cascading hierarchy for the biological cycle

CTI recognizes different types of recovery in both technical and biological cycles. Figure 18 shows the generic cascading hierarchy according to their valorization levels for biodegradable products, by-products or waste streams returning to the biological cycle.

Note that this hierarchy only accounts for recovery through the biological cycle (left side of the Ellen McArthur Foundation butterfly diagram). The top bar summarizes recovery through the technical cycle but could entail any of the strategies in Figure 18.

Figure 18: Cascading hierarchy for the biological cycle

	Cascading hierarchy | Biological cycle	Actual Recovery
High valorization	Recovery through technical cycle (e.g., reuse, recycling, etc.)	Recovered
	Nutrient absorption through biodegradation	
Some valorization	Biogas / biomass energy recovery (under set conditions)	
No valorization	Landfill / mixed-waste incineration	Not recovered

Figure 19: Cascading hierarchy for food and food waste

	Cascading hierarchy | Food	Actual Recovery
Full use	Consumption	Recovered
High valorization	Recovery through consumption alternative (e.g., animal feed)	
Some valorization	Nutrient absorption through biodegradation	Partially recovered 50%
	Biogas/biomass energy recovery (under set conditions)	
No valorization	Landfill / mixed-waste incineration	Not recovered

Looking at the cascading of biodegradable products, by-products or waste streams suitable for recovery through the biological cycle, there is one stream that needs a modified approach: food. Since food growth and production are for the sole purpose of consumption, do not consider recovery through biodegradation instead of consumption as an equally circular recovery model. Specifically, for food the valorization hierarchy looks like Figure 19.

Note that this hierarchy only covers edible food parts. The main biological cycle cascading hierarchy covers non-edible food waste streams such as eggshells, orange peels and coffee grounds.

It is up to the company to assess the improvement opportunities to optimize the loop. Upgrading food waste recovery from partial recovery to high recovery or full use will result in a higher score on the % actual recovery and therefore the % circular outflow. The reasoning for this is that it is different from the recovery strategies in the technical cycle, where we assume that all recovery strategies take place at some time and at some place in the value chain. This is not the case for the edible streams in the biological cycle. For example, consumed food can no longer biodegrade (as food). Therefore, for biological cascading, there is a clear hierarchy of activities varying in circular nature.

Actual lifetime

Keeping products and materials in the loop to the end of their useful lives minimizes the consumption of resources and generation of waste. The **actual lifetime** indicator allows companies to monitor their performance on a product's lifetime by providing a higher score for those goods whose lifetime is longer than the industry average.

A product's lifetime is intended as the duration of the period that starts at the moment a product is released for use after manufacturing or recovery and ends at the moment a product becomes obsolete.[39] Its durability drives a longer product lifetime, meaning the ability to "function as required, under specified conditions of use, maintenance and repair, until a limiting event prevents its functioning."[40]

A product's technical lifetime and functional lifetime enable its durability. The technical lifetime is the time span or number of usage cycles for which a product is considered to function as required, under defined conditions of use, until a first failure occurs. The functional lifetime is the time a product is used until the requirements of the user are no longer met, due to the economics of operation, maintenance and repair or obsolescence. While the technical lifetime is part of the intrinsic properties of the product, the conditions created around the product determine its functional lifetime.[41]

We developed CTI's actual lifetime indicator with the intention of driving companies to develop an understanding of a product's average life duration.[40] This is the lifespan that the product actually experiences, on average, rather than design life or warranty period.

The actual lifetime indicator provides a higher score for products that stay in use for longer than the industry average and the calculation is as follows:

actual lifetime

$$= \frac{\text{product actual lifetime}}{\text{average product actual lifetime}}$$

Companies can calculate the actual lifetime in number of years OR number of use cycles.

In calculating this indicator companies may determine a reference lifetime value, for example lifetime (in time span OR number of use cycles) of the prior product version or, if appropriate, an average of at least a few prior products; or the lifetime (in time span OR number of use cycles) of an "industry average" product, which is either:

- Calculated using a methodology consistent with both LCA best practices and with the methodology used elsewhere in the company's CTI response; or
- Obtained from reference literature, taking care to use the most up-to-date data and, at a minimum, not using data that is too outdated to reflect the current state of the industry.

NOTE

A product's design should ensure that its durability and useful lifetime have a direct relationship with its environmental impact and embodied energy.

EXAMPLE

The average product lifetime of a mattress is 10 years. A mattress that has a lifespan demonstrably higher than the industry average (e.g., 15 years) will have a positive actual lifetime score.

(Lifetime data source: Product Life Database, International Living Future Institute).

The strength of the indicator relies on the methodology that companies adopt to calculate the actual lifetime of assessed products. For example, reference products would target the same overall customer base, in similar geographies and timeframes. Widespread adoption and comparability will depend on the harmonization and standardization of an appropriate methodology to measure lifetime by relevant industries and sectors.

In calculating the actual lifetime indicator, companies should aim to capture the actual average life duration of the product under scope. In developing an understanding of the average life duration of their products, companies may consider tracking maintenance, repair and upgrade operations the product underwent and the number of its successive users.[43]

The actual lifetime indicator measures the performance for finished products. Components and materials are currently not within the scope of this comparison.

Companies may use CTI's actual lifetime indicator for durable products that require no or minimal consumption of water, electricity or detergents during use, whose highest environmental impact issues from the production or disposal phases, such as furniture, clothing or technical equipment.

Durable products that consume electricity, water or detergents during use, such as home appliances or electronical goods and equipment, should always consider the optimal replacement rates of products under scope.

Do not apply CTI's actual lifetime indicator to non-durable products with an intrinsically short lifespan (e.g., fast-moving consumer goods).[44]

EXAMPLE

A computer mouse is designed to last 6 years but the average lifetime of a computer mouse is 4.5 years. The actual lifetime indicator in CTI will provide a positive score for companies whose computer mouse stays in use demonstrably longer than the industry average. (Lifetime data source: Product Life Database, International Living Future Institute)

VALUE THE LOOP

This module helps companies gain insights into how effective they are at generating revenue per unit of material they depend on.

Circular material productivity

The first indicator launched in this module is circular material productivity, which expresses the value a company generates per unit of linear inflow. The outcome produces a value that companies can monitor over time. The calculation is:

circular material productivity

$$\frac{\text{revenue}}{\text{total mass of linear inflow}}$$

An increase in this indicator demonstrates a successful decoupling of financial growth from (linear) resource dependence.

CTI revenue

The CTI revenue indicator creates an objective and quantitative bridge between a company's performance in closing the loop on the resources it uses and how that affects a company's financial performance.

To calculate CTI revenue for a product:

CTI revenue (product)

$$\frac{\text{\% circular inflow} + \text{\% circular outflow}}{2} \times \text{revenue}$$

To calculate CTI revenue for a business unit or company, sum up all the product CTI revenue calculated:

CTI revenue (company)

$$\sum \begin{matrix} \text{CTI revenue A} \\ +\text{CTI revenue B} \\ +\text{CTI revenue C} + \ldots \end{matrix}$$

This calculation allows a company to attribute more of its revenues as circular through product portfolio steering by (1) innovating new products that are more circular, (2) improving the circularity of the existing product portfolio, and (3) driving sales of more circular products in the portfolio.

CURRENCY SELECTION

The company should use the same currency that it uses in its financial reporting. In cases where the company uses multiple currencies, consider the scope of the CTI assessment and the objective to determine the most effective currency for informing the targeted decision-makers.

CTI REVENUE

A product that qualifies as 25% circular (weighted average of its circular inflow and circular outflow) and generates USD $1 million in sales would contribute USD $250,000 towards the company's total CTI revenue.

Companies should input their CTI revenue into a table like Table 4, allowing them to observe how their revenues fall across circular performance tiers (e.g., deciles). The more bottom-heavy a company's revenues are in this table, the less the portfolio depends on a linear economic model. Note that the 0% and 1-10% performance tiers are (largely) linear and do not add much to the CTI revenue amount. The ambition should be for companies to move their product portfolios down the table over time.

In calculating circular revenues with this method, the CTI revenue indicator:

- Directly links circular performance between mass flows and financial results.
- Allows companies to identify new and continuous improvement opportunities and set quantitative targets (i.e., a 60% circular product still has the potential to move to higher tiers).
- Enables consistent communication with executives and investors
- Minimizes additional effort by using the results from the Close the Loop indicator.
- Avoids subjective qualification of defining a "circular product"
- Complements binary-qualification (YES/NO) circular indicators by providing more granularity through the three pillars of circularity: circular inflow, recovery potential (design) and actual recovery.
- Provides more granular insights into linear risk and circular opportunities of a company's portfolio.
- When using the CTI online tool, automatically calculate this indicator based on the data collected through the circular inflow and circular outflow indicators supplemented with product (group) revenues.

Table 4: CTI revenue

Company A - CTI revenue

% circularity (Close the Loop indicator)	Revenue (USD $)	Weighted average revenue" (% circularity x revenue)
0%	USD $400 million	USD $0 million
1-10%	USD $150 million	USD $7.5 million
11-20%	USD $200 million	USD $30 million
21-30%	USD $150 million	USD $37.5 million
31-40%	USD $50 million	USD $17.5 million
41-50%	USD $30 million	USD $13.5 million
51-60%	USD $20 million	USD $11 million
61-70%	-	-
71-80%	-	-
81-90%	-	-
91-100%	-	-
Total revenues	**USD $1 billion**	
CTI revenue		**USD $117 million (11.7%)**

IMPACT OF THE LOOP

GHG impact

To calculate the GHG emission savings associated with circular strategies, allocation rules need to be used to navigate the complexity of who carries the burden of emissions. The system model: "Cut-off by classification" was used.[45] This system model maintains to the following rules:

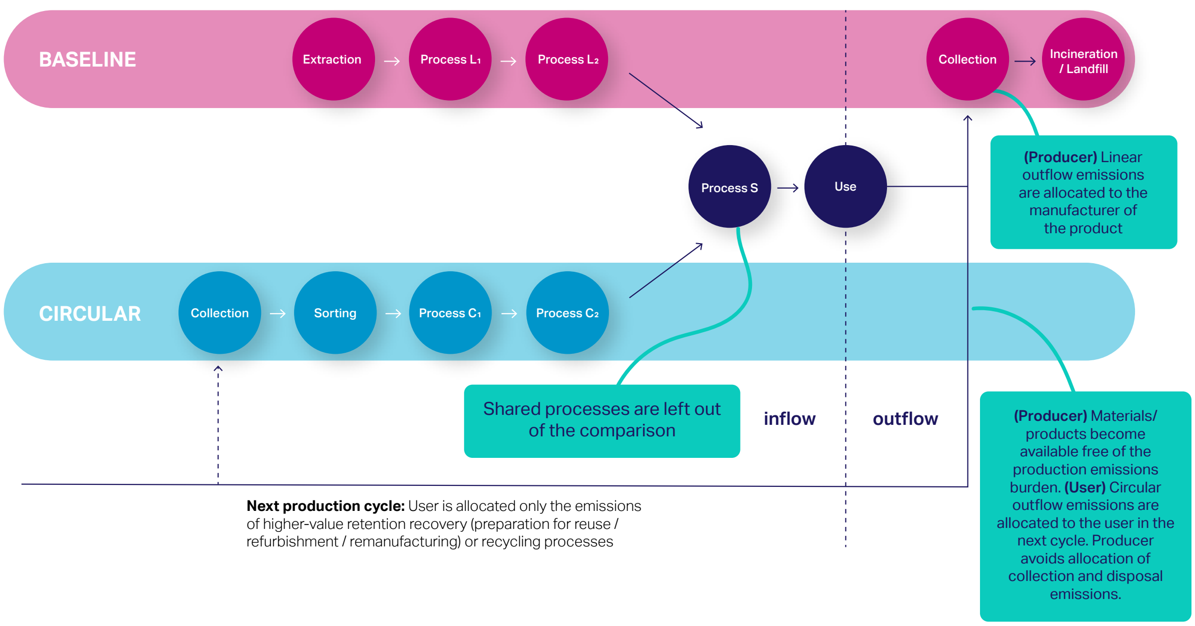
- The producer of a material or product is fully accountable for the GHG emissions of the production of that material or product. Even if that becomes a secondary material, part or product after use, is reused, remanufactured, refurbished or recycled.
- The non-virgin material part or product becomes available free of GHG emissions burden for the user of this non-virgin material or product in the next production cycle.
- The user of this non-virgin material or product is only allocated the GHG emissions of preparation for reuse (preparation for reuse activities cluster the emissions of the reuse, remanufacturing and refurbishing)[46] or recycling processes needed.
- For linear end-of-life disposal (incineration and landfill), all emissions associated with linear disposal processes are allocated to the producer as these are not assigned to other users.

Figure 20 shows the individual process steps included in the comparison.

For CTI Tool users:

GHG impact (Inflow Technical Materials) is only available for CTI Tool Pro users. Note that the CTI Tool uses ecoinvent database V3.8 to establish the emissions factors per unit of materials for both the virgin and non-virgin (recycled) version of the material assessed. Companies that do not use the tool can use the collected for % material circularity and follow the methodology outlined in this report to understand the GHG impact of material flows by combining these with emission factors from credible databases or supplier specific sources. A list of recommended secondary emissions factors databases is available in WBCSD's Pathfinder Network guidance (page 31).

Figure 20: Setting the system boundaries of baseline and circular material flows



The "Allocation, Cut-off by classification" system model leads to the following calculations to assess the potential GHG emissions savings of circular strategies:

Inflow technical materials– Recycled content

The outcome of this calculation is the % GHG emissions savings realized if the material is made out of 100% recycled content versus the GHG emissions related to the current composition.

The impact on GHG emissions is calculated using the following formula for the absolute amount of CO_2 equivalent:

$$(M_x \times GHG_{xr}) - [(M_{xr} \times GHG_{xr}) + (M_{xv} \times GHG_{xv})]$$

Or the following formula for a percentage value:

$$\frac{(M_x \times GHG_{xr}) - [(M_{xr} \times GHG_{xr}) + (M_{xv} \times GHG_{xv})]}{(M_{xr} \times GHG_{xr}) + (M_{xv} \times GHG_{xv})} \times 100$$

M_x: Total weight material X
GHG_{xr}: GHG emission factor recycled material X
M_{xr}: Weight of recycled content material X
M_{xv}: Weight of virgin content material X
GHG_{xv}: GHG emission factor virgin material X

As an example, consider a 700-gram PET cover that consists of 5% recycled content. The GHG emissions factor for the sourcing of the recycled content is 1.7 kg CO_2-eq/kg material and 3.1 kg CO_2-eq/kg material for the virgin content.[47]

Based on the calculation below, the company will obtain a 44% reduction in GHG emissions when it increases the recycled content of the PET cover from 5% to 100%.

$$\frac{(0.7 \times 1.7) - [(0.035 \times 1.7) + (0.665 \times 3.1)]}{(0.035 \times 1.7) + (0.665 \times 3.1)} \times 100$$

When the materials for which the GHG emissions factor for the circular version is not available in existing databases, the company can calculate the GHG impact by combining the GHG footprint of the individual process steps needed to source the recycled material (see Figure 20).

For CTI Tool users:

The CTI Tool has chosen the Intergovernmental Panel on Climate Change (IPCC) as its impact assessment model as it has a 100-year time frame. The primary (first) production of materials is always allocated to the primary user of a material. If a material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. As a consequence, recyclable materials are available to recycling processes and secondary (recycled) materials bear only the impacts of the recycling processes.

The GHG factors used in the CTI Tool are based on global averages using a market approach where available. Factored in the values are the processes of virgin mining (linear), collection and recycling (circular) and transport (see system boundaries outlined in Figure 20).

For companies performing the assessment outside of CTI Tool, we recommend using primary data where available. If the company is deriving GHG emissions from databases, it could adhere to choices made for other purposes or take the above-mentioned impact model and time frame as a default.

Inflow – Higher value retention and closed loop recycling

Guidance for users of secondary products/materials

The GHG impact related to the collection, sorting and recovery methods (recycling and "higher value retention") are accounted for at the inflow side in CTI as "non-virgin materials" based on the "Allocation, Cut-off by classification" system model. In closed loop recycling – and when materials are recovered by a third party – we propose the following emissions formula to calculate the absolute emissions savings on the inflow side:

$$(M_t \times GHG_r) - (M_r \times GHG_r) - (M_v \times GHG_v)$$

Or the formula for the percentual savings:

$$\frac{(M_t \times GHG_r) - [(M_r \times GHG_r) - (M_v \times GHG_v)]}{(M_r \times GHG_r) + (M_v \times GHG_v)} \times 100$$

M_t = total mass material

GHG_r = emission factor of the recovery methods ($kgCO_2$ / kg)

M_r = mass recovered material used (either via preparation for reuse, or recycling)

GHG_v = emission factor of the virgin material ($kgCO_2$ / kg)

M_v = mass virgin material used

The outcome is the % GHG emissions savings realized if the material is made out of 100% virgin content minus the emissions associated with the recovery method. The indicator gives insights into the amount of GHG emissions saved (by the user of the recovered materials) if the materials go from the current % recycled/prepared for reuse content to 100% recycled/prepare for reuse content.

Higher value retention recovery strategies facilitate the cycling of products and components within a circular economy.

CTI users are encouraged to explore opportunities for recovery via reuse, refurbish or remanufacturing whenever these are available to them.

Recent research on higher value retention recovery strategies demonstrates their significantly lower environmental impact potential versus conventional product life cycles.

For more information, see Russell, J.D. & Nasr, N.Z. (2023). "Value-retained vs. impacts avoided: the differentiated contributions of remanufacturing, refurbishment, repair, and reuse within a circular economy". *Jnl Remanufactur* 13, 25–51 (2023).

Outflow – Technical materials

Producers

The use of the “Allocation, Cut-off by classification” system model leads to a situation in which GHG emission savings are observable once a product or material is recovered with a circular recovery strategy:

- Circular recovery methods: preparation for reuse or recycling will not lead to any emissions burden for the producer and therefore represent savings compared to the linear disposal method.
- Linear disposal methods: incineration or landfill will lead to an emissions burden for the producer of the unrecoverable products and materials.

Formula for the absolute savings:

$$(M_r \times GHG_{xl}) - (M_t \times GHG_{xl})$$

Formula for the relative savings:

$$\frac{(M_r \times GHG_{xl}) - (M_t \times GHG_{xl})}{(M_t \times GHG_{xl})} \times 100$$

M_t = total mass material

GHG_{xl} = emission factor of the linear recovery method: incineration, landfill

M_{xr} = mass to be recovered outflow

GHG_{xr} = emission factor of the mass to be recovered = 0 kgCO /kg

M_{xl} = mass linear outflow

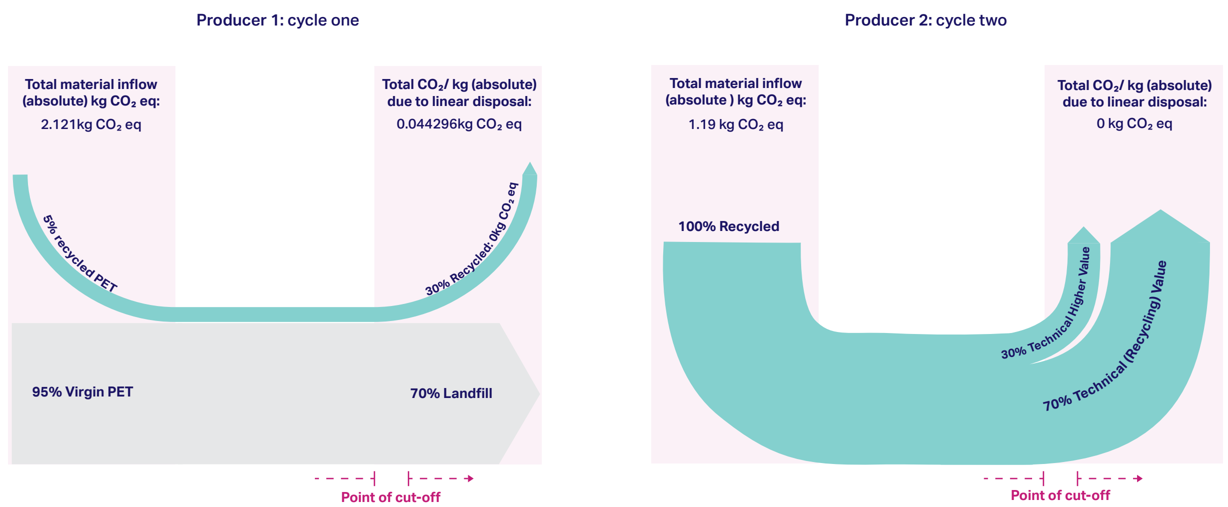
The outcome of the formula is the % GHG emissions savings compared to a scenario in which 100% of the material is disposed of in a linear way, via incineration or landfill. It gives insights into the amount of GHG emissions a producer can save, if the products or materials under scope are recovered through higher value retention recovery or recycling versus incineration or landfill. Based on the “Allocation, Cut -off by classification” system model, savings are equal to the emissions of the % of material that avoids incineration or landfilling because the producer makes them available for recovery for use by another user in a following cycle.

Building on the example used for inflow, consider that the 700-gram PET laptop cover is 30% recycled and 70% incinerated. The GHG emissions factor for the incineration of PET is 0.0904 CO2 -eq/kg.[48] According to the "Allocation, Cut-off by classification" system model, the producer of the PET laptop cover accounts for the emissions associated with linear disposal methods. In this case, the producer of the PET is allocated the GHG emissions associated with 70% incineration. In the example, potential emissions savings from transitioning to a 100% circular scenario would be 70%. With the current 30% recycling, the producer saves 30% of emissions that otherwise would be allocated for the linear disposal of the cover. If the producer works with value chain partners to increase the recycling rate of the cover to 100%, this would provide an additional 70% savings on the emissions allocated for the linear disposal through incineration or landfill.

$$\frac{(0.21 \times 0.0904) - (0.7 \times 0.0904)}{(0.7 \times 0.0904)} \times 100$$

Since the producer is not allocated emissions for the incineration and landfilling of the product or material, the emissions savings are 70%. This is because the emissions savings are based on the transition from 70% incineration to 0% linear disposal. In this approach, users of non-virgin materials benefit from materials that are free from the burden of production emissions while producers of primary materials benefit from incentivizing the recovery of products and materials to avoid high landfill or incineration emissions.

Figure 21: Potential emissions savings of transitioning to circularity for a PET laptop cover



Nature impact

Impact on nature is calculated using the following formula for each raw material separately:

$$(M_{rx} \text{ X } Extent) \text{ X } (M_{xrp} \text{ X } Condition\ Change) \text{ X } (M_{xrl} \text{ X } Significance)$$

- **M_{xr}:** total weight raw material X
- **M_{xrp}:** land use type and land use intensity raw material X
- **M_{xrl}:** sourcing location raw material X
- **Extent** (in km^2) of land occupied: the allocated physical area of habitat occupied due to production of raw materials for inflow. Based on estimated yield per area of raw material. The smaller the extent the better the performance on this metric.
- **Condition change** (from 0-1) of biodiversity on the land: the "quantity" or "amount" of biodiversity lost on the occupied land, relative to an undisturbed reference state, based on the type and intensity of land use. Condition change is based on biodiversity loss co-efficient calculated from Mean Species Abundance (MSA), ranging from 1 (intact habitat) to 0 (loss of all biodiversity). The smaller the condition change from an undisturbed reference state to current land use the better the performance of a company on this metric. Apart from MSA a company could use another metric to measure condition change. See Annex II: Choice of Land use metrics for more details.
- **Significance** (on a scale of 1 to 5) of biodiversity impacted: the "value" of the biodiversity, represented by the types of biodiversity present in the area and how significant their loss would be for biodiversity protection and recovery globally. CTI recommends using the STAR metric[49] as it is the best metric currently available data for setting company targets to reduce species extinction risk. The lower the significance of a particular area, the smaller the global biodiversity impact of the sourcing activities. Apart from STAR-t scores, a company could use another metric to measure significance. See Annex II: Choice of land-use metrics for more details.

The resulting unit represents "threat-weighted quality square kilometers", where threat refers to extinction risk of terrestrial vertebrate species (mammals, birds, amphibians). The smaller the number, the smaller the associated biodiversity land use impacts.

Nature Impact

The nature impact score measures the land use impacts of material extraction and cultivation. It represents the loss of quality-adjusted km_2 that a company is responsible for, weighted according to the global extinction threat associated with sourcing locations.

Land-use impacts associated with manufacturing processes are not included (but can also be estimated using LCA-based methods), while any additional primary sourced parts introduced into circular processes, (e.g., new elements added in repaired products) are considered within the standard framework.

STAR metric

CTI adopts the Species Threat Abatement and Restoration (STAR) metric to assess Significance. STAR is accessed through the Integrated Biodiversity Assessment Tool (IBAT), which requires an IBAT license. Country-level STAR data will be freely available through using the WWF biodiversity filter. At present few suitable Significance metrics are available globally and free of charge for commercial use. Another option is the Global extinction probability (GEP) metric created by Verones et al. (2022).

Scoring card

For the purposes of simplification and usability, the assessment can be simplified through use of a score card (Table 5). The score card provides broad value categories, with quantitative lower and upper bounds, for extent, condition and significance. Categories are selected based on the best available information, applying plausible assumptions. This approach requires only estimates for the scale, impacts and location of sourced materials, rather than exact quantification. A more comprehensive, fully quantitative approach can be applied in a data-rich scenario where companies wish to fully quantify their land-based biodiversity footprint.

EXAMPLE

For example, if the extent of land required to produce all of the cotton or palm oil a company uses in its value chain is estimated to be 1 – 10km^2 the extent would fall into the "small-medium" category. If intensively farmed, the condition change is likely to be at least loss of 0.7 MSA and therefore the category will be "very large". If organically farmed, the MSA loss may fall into the category of 0.5 – 0.7 and therefore be considered "large". Within CTI, organic farming and materials grown using regenerative agricultural practices are considered renewable and therefore circular in CTI. Within the nature indicator, this "renewable" criteria is expressed in the improvement in the condition change. Finally, if it is sourced from a highly biodiverse country (e.g., in the tropics) the significance may be "very high", while if it is sourced from a less biodiverse country (e.g., in northern Europe) the significance may be "moderate" or "low".

Table 5: Nature Impact score card, which uses broad "bins" for rapid estimation with uncertain data/assumptions

Estimated extent (km²)	~0	0- <0.1	0.1-<1	1-<10	10<100	100<1,000	1,000<10,000	>10,000
Category description	Negligible	Very small	Small	Small-medium	Medium-large	Large	Very large	Extremely large
Score for extent dimension (E)	0.01	0.1	1	10	100	1000	10000	Use actual area estimate

Estimated condition change (on 0-1 scale, based on MSA)	0- <0.1	0.01-<0.1	1-<0.3	0.3-<0.5	0.5-<0.7	>0.7-1
Category description	Very small	Small	Small-medium	Medium-large	Large	Very large
Score for condition dimension (C)	0.01	0.1	0.3	0.5	0.7	1

Estimated significance (80th percentile STAR-t score)	0- <10	10<100	100<1,000	1,000<10,000	10,000<100,000
Category description	Low	Moderate	High	Very high	Highest
Score for significance dimension (C)	1	2	3	4	5

TOTAL SCORE = E x C x S

How to treat types of circular inflow

Estimating the land use required for materials with recycled, remanufactured, refurbished and reused content can be complex as these processes are specific to the materials being processed. The nature indicator aims to provide a simplified, initial screening on the pressure on nature through land use. Therefore we made different assumptions on how to treat the different types of inflow (Table 6).

Table 6: Description of assumptions and scoring procedures for different circular inflows

Type of inflow	Treatment in scoring	Reasoning
Reused	Assumed burden free, nature impact score is zero.	No changes are made except for cleaning and minor repairs, this inflow is considered burden free from the perspective of land-use impacts on nature, since there is effectively zero land use linked to the process of making a product available for a new life cycle.
Repaired, refurbished	Extent assumed to be approaching zero and therefore "negligible" in the scoring framework.	There will be small land-use impacts for the inputs and processes required for these circular inflows (e.g., cleaning, small volumes of new materials added, energy for sorting and treatment). However, the inflow impacts attributable to a company are difficult to quantify and small enough to be negligible in the context of this scoring framework.
Remanufactured		
Recycling		
Renewable	No assumptions – follow the same procedure as for linear materials.	Renewable materials are treated the same as for linear materials. Renewable alternatives will most likely outperform the linear alternatives on the "condition" variable due to improved land-use practices.

5 Analyze
Interpret results

This section focuses on interpreting the results for decision-making. Companies should involve the relevant decision-makers in this part of the process.

The results from the CTI calculation provide the quantitative foundation for identifying, prioritizing and implementing circular initiatives.

CURRENT PERFORMANCE AND PERFORMANCE OVER TIME

Current performance

We developed CTI for wide applicability across various companies, industries and value chains. As performance is likely to vary substantially depending on the company's characteristics, the model does not subjectively judge what "bad" or "good" performance is. CTI empowers companies to study their own potential for improvement by examining the percentage of their business still considered linear. Analyzing the underlying indicators is relevant to understanding what is necessary to increase the level of circularity.

Performance over time

The most valuable insights might come from tracking performance over time. A company can compare progress to any time-bound goals, objectives or targets that it has formulated. While a different methodology, a company could also compare an increase or decrease in circularity to the change in performance on a global level (such as Circle Economy's Circularity Gap Report (CGR)[50]) or on an industry level (either via governments or via aggregated data from companies or industry associations). If performance does not meet the expectations, the company may further analyze the underlying indicators and parameters that influence their outcomes.

MEASURING CIRCULARITY

WBCSD often cites Circle Economy's Circularity Gap Report (CGR) as a benchmark for the circularity of the global economy. However, due to their respective objectives, there are key differences in the CTI and CGR methodologies that make it difficult to directly compare results. Whereas WBCSD developed CTI to inform and enable companies in their circular transition, Circle Economy devised CGR to establish a macroeconomic understanding (e.g., national, regional or global). Specific differences between the two methodologies include:

- CGR includes the entire material footprint of the specific economic system or value chain. CTI focuses on the inflow and outflow of a single company.
- CTI makes a distinction between potential and actual recovery, where CGR only observes actual recovery.
- CGR considers a stream circular only when it is coming from a circular origin **and** it is fully recovered again. CTI makes a split between inflow and outflow, each of it contributing to roughly 50% of the total score.
- CGR includes the resources consumed for energy use. These resources are captured by CTI in a separate indicator on renewable energy use.

WBCSD and Circle Economy are currently exploring options to align the two metrics to provide users with the benefits of both approaches.

ANALYSIS OF THE UNDERLYING INDICATORS: CIRCULAR INFLOW AND CIRCULAR OUTFLOW

The results are often based on a broad range of flows that enter and leave the company, which can differ significantly on the mass and circularity parameters.

The mass of flows

A mass-based indicator means heavier material flows have a greater contribution to the percentage. A relevant assessment is to list the linear flows from largest to smallest mass. Closing the loop on the larger mass streams will provide a larger contribution to the level of circularity. However, this may result in the overlooking of other parameters, such as critical or priority.

The circularity of flows

GUIDANCE FOR THE TECHNICAL CYCLE

The circularity of the inflow in the technical sphere depends on the characteristics of the flows to be non-virgin. The opportunity for improvement is in assessing the characteristics of linear flows and exploring renewable (moving towards the biological cycle) or non-virgin alternatives.

The circularity of the outflow contains two components: recovery potential and actual recovery. To improve recovery potential, the analysis focuses on opportunities to optimize the design. For example, modular design, design for disassembly, repairability, high recyclability by using mono-materials, etc.

Improving actual recovery requires different actions. For example, adopting new business models, such as product-as-a-service or buy-back/take-back schemes, will likely significantly improve actual recovery rates. Another option is to collaborate with value chain partners that drive circularity, bringing more clarity into mass flows down the value chain and a greater ability to develop a shared value proposition.

GUIDANCE FOR THE BIOLOGICAL CYCLE

Bio-based flows are not circular by definition. Bio-based materials need to be at least renewable and preferably regenerative. Consider bio-based inflow as circular and label it as renewable if it is sustainably grown and harvested at a rate that natural growth and replenishment can occur after extraction. The circularity of flows in the biological cycle therefore depends on the stream management characteristics: if streams are not minimally sustainably managed, label them as non-renewable. Therefore, the opportunity for improvement to have more circular inflow for bio-based streams is to increase the share of sustainably grown materials, for example by using certified sources.

The circularity of the outflow contains the same two components in the biological cycle as for the technological cycle: recovery potential and actual recovery. In the biological cycle biodegradability and toxicity determine the recovery potential (see the Organisation for Economic Co-operation and Development (OECD) biodegradability testing standard). Therefore, the improvement potential is to ensure that the bio-based product is biodegradable and does not contain restricted substances beyond threshold levels. In the case of hybrids (products containing both bio-based and technical flows) it is possible to improve the recovery potential through the design: separating the bio-based and technical components should be made possible by design.

Improving actual recovery for products, by-products and waste streams moving in the biological cycle will depend on the type of valorization (refer to the hierarchy for the bioeconomy on page 61). For non-edible bio-based flows the company can consider valorization through technical cycle strategies and explore the related new business models. As these strategies are unlikely to be endless for bio-based materials (i.e., paper fiber loses length and strength with each recycling loop, leading to maximum recycling of around seven times) the flow needs to be prepared for recovery in the biosphere as well (i.e., through biodegradation and/or nutrient recovery). For edible flows, the key is for an actual living organism to consume it to be considered recovered. Therefore, avoid food waste and losses within the value chain and at the end-consumer to increase circular outflow. Although not fully circular, biodegradation of edible flows will provide a 50% recovery score (whereas for non-edible biodegradable streams, biodegradation is 100% recovery) and therefore could provide a slightly better alternative over landfill.

IMPORTANT CONSIDERATIONS ON BIODEGRADABILITY

Not all biodegradable products are bio-based or made from renewable resources: some fossil-based polymers are fully biodegradable (e.g., polybutylene adipate-coterephthalate (PBAT) or polycaprolactam (PCL)).

Not all bio-based products are biodegradable. While biodegradability is a property inherent to some bio-based products, many of them are durable and do not biodegrade. Biodegradation is a chemical process while disintegration is a physical process. For a product to decompose completely both must occur.

Biodegradation is highly dependent on factors such as temperature, time and the presence of bacteria and fungi. Higher temperatures and controlled conditions make industrial composting the most ideal environment for plastics to decompose.

Source:

This content is drawn from an EU project funded by the Horizon 2020 program InnProBio: Biodegradability, Exposing some Myths and Facts.

EXAMPLES FOR THE TECHNICAL CYCLE

Non-virgin inflow

A construction company could increase circularity levels by replacing virgin steel beams with reused beams or recycled steel.

Renewable inflow

A cosmetics company could increase circularity levels by replacing virgin synthetic ingredients with renewable content.

Recovery potential

An ICT company could change the design of a product to enable disassembly, allowing for repair, reuse and refurbishment.

Actual recovery – business model

An ICT company could change to a pay-per-use-business model, enabling higher collection and reuse rates.

Actual recovery – collaboration

A company producing electronic equipment could collaborate with a retailer to collect used equipment by stimulating the consumer with a take-back scheme, ensuring the recovery of parts and materials.

EXAMPLES FOR THE BIOLOGICAL CYCLE

Non-virgin inflow

A paper company could increase the recycled content of paper and card box.

Renewable inflow

A furniture manufacturer could only use Forest Stewardship Council (FSC)-certified wood to ensure renewability and alignment with a cycle of growth and replenishment.

Recovery potential

A cosmetics company could change the design of a product to ensure the separation of biological and technical streams of hybrid products, allowing for biodegradability of the bio-based streams.

Actual recovery

A fragrances company could change to a higher valorization type, enabling full recovery of its residual streams by using them as input for the food industry.

A supermarket could provide almost expiring products to food banks to avoid food waste and increase the recovery.

WATER AND ENERGY

Water circularity

A company can improve its water circularity in two ways:

1. Better demand management, reducing the overall use of water, with a focus on reduction of linear water in- and outflows;

2. Substitute linear water in- and outflows with circular water in- and outflows.

Since local water source demand is a combination of all local stakeholder needs (other businesses, communities, the ecosystem itself) it is important to consider opportunities for improvement at a catchment scale and look through a wider lens when considering any opportunities for improvement. Companies must engage with other stakeholders in the water catchment area to collaborate on potential circular solutions.

Renewable energy

This indicator demonstrates the percentage of renewable energy used. In theory, a fully circular economy runs on renewables and therefore the goal should be to reach 100%. Opportunities for improvement are:

- Decreasing overall energy consumption (relative to increasing the % of renewable energy used), or
- Substitute fossil fuels with renewable alternatives.

OPTIMIZE THE LOOP INDICATORS

% critical materials

The results of this indicator demonstrate to what extent a company is dependent on materials identified as critical. Even if the percentage of critical materials is small, it may be relevant to further analyze it to understand:

- The diversity in critical materials
- The substitutability of critical materials
- The absolute use of critical materials
- Revenue dependent on critical materials (revenue at risk).

The characteristics of the critical materials

A company may have multiple critical materials in its inflow. It is important to understand the nature of these materials. Not all materials defined as critical have the same score on criticality, which is a combination of supply risk and regional economic importance. It can be relevant to evaluate the critical material flows based on size, revenue dependent on the flow, and the relative criticality of the material.

WATER CIRCULARITY

Increase circular water inflow

If located in a water-scarce area, a company can explore opportunities to contact other businesses to explore sourcing third-party water directly from other users.

Increase circular water outflow

When outflowing water circularity is low, an easy step the company can take is to either treat all its discharge water to the standards of the local water regulations or make sure of its outsourcing to a third party (water treatment plant) that upholds the same standards.

Increase internal circulation

Exploring opportunities to reuse or recycle water flows from the company's own processes both increases internal circulation and improves demand management, automatically reducing the need for potential linear water in- or outflow.

NATURE OF A CRITICAL MATERIAL

- What material is it?
- What is the respective criticality of the material?
- Is the material virgin or secondary?

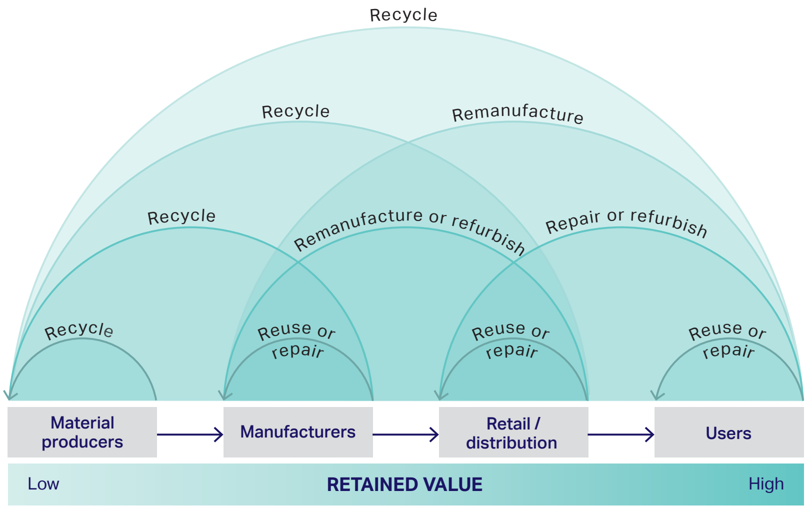
Substitutability of the critical materials

If it is possible to substitute the critical materials with alternative, non-critical materials with the same or similar functionality, a company may partly mitigate its risk. Therefore, it is relevant to assess whether any substitutes are available.

The absolute use of critical materials

Even if the relative use of critical materials (in percentage) is low, the absolute amount or costs of critical materials could reach a point where absolute scarcity, price increase and price volatility affect business continuity. Therefore, it can be relevant to also monitor the absolute use of critical materials.

Figure 22: Recovery types



Recovery types

GUIDANCE FOR THE TECHNICAL CYCLE

In the technical cycle, the assumption is that all recovery strategies should take place at some time at some place in the value chain. The opportunities for an individual company to shift between recovery types will largely depend upon the type of company and its position in the value chain. Nonetheless, a company may evaluate the opportunities to ensure the outflow retains the highest value possible by moving towards higher value maintaining strategies (i.e., reuse over recycling). A company explores the effects of innovative business models such as product-as-a-service or sell-and-buy-back and also less-radical changes such as new value chain collaborations on enabling the shift towards higher value-retaining recovery strategies.

GUIDANCE FOR THE BIOLOGICAL CYCLE

In contrast to the technical cycle, the assumption that all recovery strategies take place at some time at some place in the value chain does not hold for the biological cycle. Therefore, the driver of every individual company should be to climb up the hierarchy to enable high valorization strategies. A company may collaborate with other partners in the value chain to look for alternative recovery types or set up adjusted logistics itself to achieve higher valorization of its outflow.

Actual lifetime

The goal of a circular economy is to retain the value of resources, products, parts and materials by creating a system that allows for renewability, long life, optimal (re)use, refurbishment, remanufacturing, recycling and biodegradation. Transitioning to a circular economy entails completely rethinking how products are designed, produced and discarded, with a view to optimizing resource loops across the value chain.

Environmental concerns and consumer demand are driving legislation to support product longevity, with the aim of maximizing value created per each unit of resources. New legislation spanning countries rewards companies that promote product durability (e.g., repairability index, right to repair) and discourages premature or planned obsolescence.

With CTI's actual lifetime indicator, companies can assess their performance in effectively slowing down resource loops.

We have developed the indicator to drive companies to monitor what actually happens to products when they leave the company's gate and identify actions that will promote longer useful lives for products, including through reuse, refurbishment and remanufacturing.

A product can achieve a longer than average actual lifetime when it's designed for maximum performance across both technical and functional lifetimes. While the technical lifetime is part of the intrinsic properties of the product, the conditions created around the product determine the functional lifetime.[51]

Companies may improve their actual lifetime indicator score by designing products and product ecosystems that enable maximum technical and functional lifetimes. They can achieve this by improving product design for durability and reliability, modularity and part standardization, ease of maintenance and repair, upgradability, disassembly and reassembly, and component recovery[52] via refurbishment or remanufacturing.

Along with designing for durability, companies will achieve longer lifetimes for their products by preventing premature obsolescence. This will entail a product ecosystem that keeps products performing, relevant, easy to use, upgradable, repairable and desirable.

NOTE

A product's design should ensure that its durability and useful lifetime have a direct relationship with its environmental impact and embodied energy.

Companies should ensure that efforts to extend the lifetime of products and materials do not harm recycling potential at the end of life.

Types of product obsolescence:

- Technological and functional – products with improved performance come to market
- Psychological (cultural or esthetic) – desire to buy more or newest version based on fashion and marketing
- Systemic – alter the ecosystem to make product more difficult to use
- Economic – loss of useful properties because cost of repair is higher than new product

Source: Policy Instruments on Product Lifetime Extension, PLE

VALUE THE LOOP INDICATORS

Circular material productivity

This indicator expresses monetary value per unit of mass. This absolute value will vary greatly across companies and it is best to use it to compare performance over time. An increase in circular material productivity demonstrates a decoupling of financial growth from material consumption.

In addition, it is relevant to compare a decrease or increase in circular material productivity externally. For example, if enough anonymized and aggregated data is available, one possible insight is that the company had a 2% increase in circular material productivity over one year while the sector had a 5% increase, which could indicate that the company has additional opportunities to seize.

Companies should consider how different factors like exchange rates, inventory and CTI revenue will affect circular material productivity over time and measure the calculation's sensitivity to such factors.

Even though the calculation for circular material productivity is not the same as that for domestic material consumption (DMC)/gross domestic product (GDP), both metrics demonstrate decoupling. Therefore, it might be interesting to compare changes in circular material productivity with the increase in DMC/GDP on a national or sector level.

CTI revenue

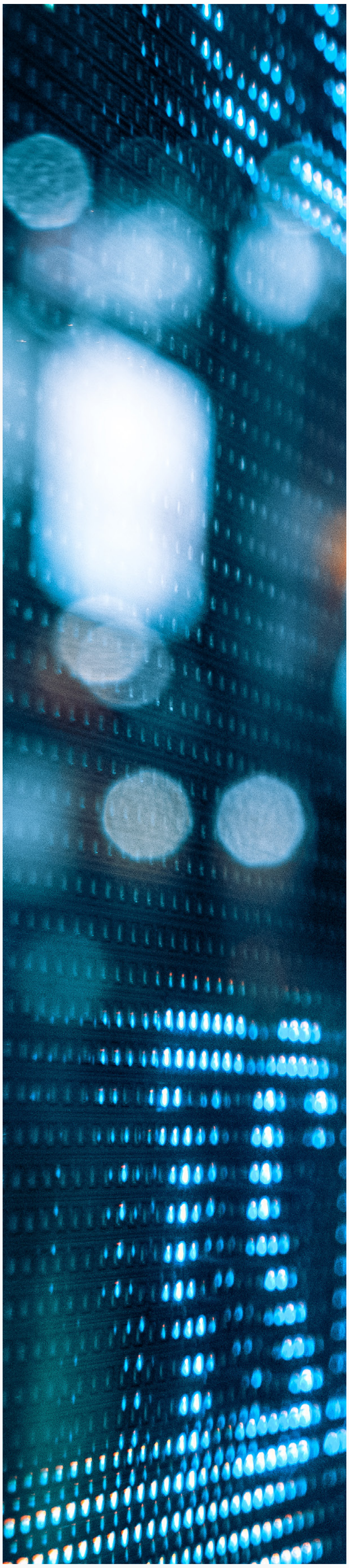
This indicator can illustrate a few insights for the company:

- Understanding the percentage of the company's total revenues derived from circularity
- How the company's revenues of more circular products compare to less circular ones
- How the company's product portfolio breaks down across Close the Loop performance tiers, highlighting where the company may want to focus improvement efforts on product circularity or sales.

On this last point, charting the company's or business unit's product portfolio across the Table 7 will help bring each of these insights to light. Within the analysis phase the company can use opportunities for portfolio steering by:

- Innovating new circular product (groups)
- Increasing the circularity of existing products, and/or
- Driving sales of more circular alternatives over less circular alternatives.

In doing this exercise, a company may find that its overall circularity score (based on mass of % circular inflow and % circular outflow) may be different from the percentage of total company revenue quantified as circular as per the CTI revenue indicator.



If a company finds that its CTI revenue as a percentage of total revenue is greater than the (mass-based) circularity % material circularity, this may imply that the company makes disproportionally more revenue off more circular products or services.

If % CTI revenue/total revenue is less than % material circularity, the company likely depends on more linear products in its portfolio to generate most of its revenue.

To analyze this further, Table 7 allows the company to observe how its revenues fall across circular deciles (e.g., 0%, 1-10%, etc.). This will show how linear its revenues are (and vice versa). The company can then use this table to adopt targets for improving the product portfolio to become more circular.

Table 7: CTI revenue

Company A - CTI revenue

% circularity (Close the Loop indicator)	Revenue (USD $)	Weighted average revenue" (% circularity x revenue)
0%	USD $400 million	USD $0 million
1-10%	USD $150 million	USD $7.5 million
11-20%	USD $200 million	USD $30 million
21-30%	USD $150 million	USD $37.5 million
31-40%	USD $50 million	USD $17.5 million
41-50%	USD $30 million	USD $13.5 million
51-60%	USD $20 million	USD $11 million
61-70%	-	-
71-80%	-	-
81-90%	-	-
91-100%	-	-
Total revenues	**USD $1 billion**	
CTI revenue		**USD $117 million (11.7%)**

The company can implement this analysis at the product group level (if there is sufficient variation within the group) or higher, including business unit or the whole company portfolio. Taking this table further, the company may wish to add additional columns on stock keeping units (SKUs) or % of total product portfolio to capture more relevant insights side-by-side. This will allow the company to see both where its revenues fall across % circularity performance tiers and where most of its products reside.

Companies should illustrate the findings of this table in graphical form, including histograms, bar and a combination of bar and line.

IMPACT OF THE LOOP

GHG impact
Inflow — Technical cycle

Companies should analyze the information derived from the Impact the Loop module in light of the % material circularity. The combination of increase in material circularity and potential for emissions savings can support companies in ranking different solutions and focusing on the largest gains from both a material flow and GHG perspective.

The result of the calculation phase is the amount of GHG emissions that can be saved if the materials go from the current % recycled content to 100% recycled content. This information can be used for internal purposes to analyze improvement opportunities. We would like to emphasize that the output is not a carbon footprint or life-cycle assessment (LCA). We strongly recommend that companies use granular approaches such as LCA or others for final decision making and external communication.

Based on the previous example, we demonstrated a 44% reduction in the GHG emissions of a plastic cover that went from 5% to 100% recycled content. In addition to a 700-gram plastic cover, the product contains a 1,500-gram aluminum frame that consists of 85% recycled content. The GHG emissions factor for the sourcing of the recycled aluminum is 1.2 kg CO_2-eq/kg material and 5.7 kg CO_2-eq/kg material for the virgin aluminum.[53]

$$\frac{(1.5 \times 1.2) - [\,(1.2752 \times 1.2) + (0.225 \times 5.7)\,]}{(1.2752 \times 1.2) + (0.225 \times 5.7)} \times 100$$

The GHG impact measurement shows a 36% reduction in GHG emissions when the recycled content of the aluminum frame is increased from 85% to 100%.

From a % material circularity perspective, there is a clear preference to start by improving the PET flow used for the cover over a marginal improvement of the aluminum frame, which is already 85% circular. Based on the GHG emissions impact measurement, the company may obtain a significant reduction in their carbon footprint by moving to 100% circular aluminum sourcing. Depending on the company's sustainability targets, the company will decide whether to include a transition to 100% circular aluminum sourcing in its action plan.

NOTE

For CTI Tool users:
In Step 5 – Analyze, companies can visualize potential emissions savings by increasing the amount of recycled content to 100% for selected materials flows.

For companies performing the assessment outside of the CTI Tool: In addition to the current vs 100% GHG impact comparison, companies with specific % recycled content objectives may find it relevant to calculate the impact that increases in % recycled content may offer in terms of GHG emissions savings.

Inflow – Higher value (reuse, refurbish, remanufacture)

Consider a company whose inflow consists out of 200 new laptops for their employees. Currently their inflow is 100% linear as the laptops are newly produced, emitting 281.2 kg CO_2eq per laptop (175.75 kg CO_2eq/kg).[54] The company is considering increasing their percentage circular inflow by purchasing refurbished laptops.

The emissions of refurbishing a laptop are 0.9 kg CO_2eq per laptop (0.375 kg CO_2eq/kg). [55] The laptop weighs 1.6 kg.

$$\frac{(320 \times 0.375) - (0 \times 0.375) - (320 \times 175.75)}{(0 \times 0.375) + (320 \times 175.75)}$$

In total -56,060 kg CO_2 can be saved (-99.7% reduction) for the transition from 0% circular laptops to100% circular laptops.

Outflow

For the outflow, the results of the calculation phase is the amount of GHG emissions that can be saved if the materials go from the current % of recovery to 100% recovery via recycling, remanufacturing or reuse. Based on the example provided for the outflow, we showed a 70% reduction in GHG emissions of a PET laptop cover that went from 30% recycling to 100% recycling. In addition to the 700-gram cover, the product contained of a 1,500-gram aluminum frame that is for 90% recycled and 10% landfilled. The emissions factor of recycling the aluminum frame is 0 CO_2-eq/kg (on the outflow end) and 0.0393 CO_2-eq/kg for the landfilling.[56]

$$\frac{(1.5 \times 0.0393) - (0.9 \times 1.5 \times 0) - (0.1 \times 1.5 \times 0.0393)}{(1.5 \times 0.0393)} \times 100$$

The GHG impact measurement shows a 10% reduction in GHG emissions when the reuse of the aluminum frame is increased from 90% to 100%. In this case the savings are based on the savings related to the 10% recovery via reuse. From the material circularity perspective on the outflow side there is a clear preference to start improving the recovery of the PET cover, since there is a marginal improvement for the aluminum frame, which is already 90% recycled.

Nature impact

The nature impact indicator helps companies understand how their circular performance impacts nature. The indicator allows for comparison between different sourcing strategies, including circular sourcing, to see which one is most effective in reducing land-use impacts and pressure on nature.

EXAMPLE

Bio-based material

Consider a car company whose material inflow consists of 6,250 tons of cotton each year for the production of upholstery. Currently 80% of the inflow is virgin inflow sourced from a farm in India that uses conventional agricultural practices (Source A, Table 8). This inflow is considered linear as conventional agricultural practices are used that do not promote renewability. The company is considering whether it should aim to convert the remainder of virgin inflow to more non-virgin content or instead go for the renewable option of organically certified cotton. Both are considered circular options.

- Source B: A farm in China with certified organic agricultural practices (Table 8)
- Source C: A cotton recycling centre in the UK (Table 9)

We plotted the extent, condition change and significance of the current state and the two circular scenarios using the scoring card in Table 8. The results show that Source C: recycled cotton is likely to be the circular alternative with the lowest nature impact related to land use. Therefore, the company may achieve synergies between circularity and nature impacts by moving to 100% recycled cotton sourcing.

Source B: organic cotton from China, is better than conventional farming in India as the on-land practices of organic farming are better for nature. Another beneficial aspect is that the significance of biodiversity in China is moderate whereas it is high in India, meaning that producing cotton in China has less of a land-use impact than it does in India. Note that organic agriculture can be less productive than conventional agriculture in the short term,[57] which may lead to a higher score on the extent indicators. We also reiterate that the impacts of conventional cotton farming via pollution, water use and GHG emissions are likely to be larger than those from organic farming but are not taken into account here.

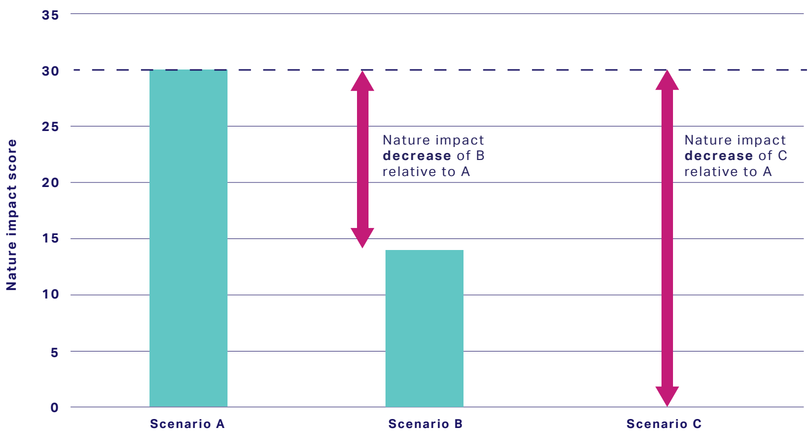
Consequently, purely from a land-use perspective, it is preferable to introduce recycled cotton instead of changing the primary sourcing.

Table 8: Illustrative example of indicator application for recycled sourcing

Source	Extent	Condition Change	Significance	Score
A. India, conventional farming	Small - medium	Very large	High	10 x 1 x 3 = **30**
B. China, organic farming	Small - medium	Large	Moderate	10 x 0.7 x 2 = **14**
C. UK, recycled	Negligible	Very large	Low	0.01 x 1 x 1 = **0.01**

The scores can also allow companies to visually compare different circular strategies, e.g., relative to each other (Figure 23) or relative to lowest (0.0001) and highest possible scores (>5,000) or with other companies for benchmarking, if scores disclosed.

Figure 23: Visual comparison of the different cotton sourcing scenarios described in the bio-based material example above



Mineral-based material:

Consider a company whose inflow consists of 100% virgin aluminum for the production of laptops. The company analyzes the land-use impacts for their inflow in 2022 sourcing 15 million kg of aluminum. The company currently sources virgin aluminum from Carajas open pit mine in Brazil (Source A, Table 9) and is considering two potential alternative sourcing strategies: sourcing linear materials from Sweden or a circular alternative from the UK.

- Source B: An underground mine in Kiruna, Sweden (Table 9)
- Source C: An aluminum recycling center in the UK (Table 9)

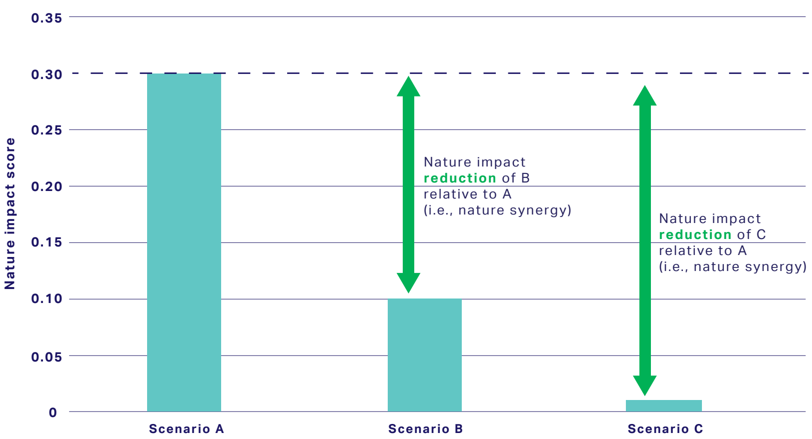
Based on published rock-to-metal ratios,[58] 15 million kg of aluminum requires extraction of approximately 105 million kg of rock. Applying simple rock density and mine site geometry calculations estimates an attributable extent of 42.75 m^2 (very small, see technical annex for details). Since this entire area is converted either into a mine pit or associated infrastructure, the condition impacts are very high. The extent and condition of an underground mine are also likely to be very small and very high, respectively, while the extent of land use from recycling is negligible (Table 9). The condition change of the recycled aluminum is very large, as the recycling center holds no biodiversity. The significance of biodiversity in Carajas Brazil is high, while it is low for Sweden and the UK.

Using the scorecard represented in 5, with results outlined in Table 9 and Figure 24, the nature impact indicator shows that Source C, the recycled aluminum from the UK, is the sourcing strategy with the lowest impact on nature. This shows that improving circular performance goes hand in hand with reducing pressure on nature.

Table 9: Illustrative example of indicator application for recycled sourcing

Source	Extent	Condition Change	Significance	Score
A. Brazil, Carajas open pit mine	Very small	Very large	High	0.1 x 1 x 3 = **0.3**
B. Sweden, Kiruna underground mine	Very small	Very large	Low	0.1 x 1 x 1 = **0.1**
C. UK, recycled	Negligible	Very large	Low	0.01 x 1 x 1 = **0.01**

Figure 24: Visual comparison of the different aluminum sourcing scenarios described in the mineral-based material example above



6 Prioritize
Identify opportunities

The insights gathered on circular performance indicate which flows have the greatest potential for improvement. However, to use this information to make decisions and prioritize, the company might want to understand how circular performance relates to linear risks. By assessing company exposure to risks, and by subsequently evaluating opportunities via a business case, companies can start prioritizing actions. For this section, we refer to WBCSD's 2018 Linear Risks report,[59] which explains circular risk and opportunities.

IDENTIFY LINEAR RISKS AND CIRCULAR OPPORTUNITIES

As it is possible to link the indicators used in the assessment to linear risks and circular opportunities, these connections can give the company an initial picture of what kind of risk and opportunities are relevant (see Table 10).

Table 10: Examples of risks and opportunities.

Note: Might contain overlap; list is not exhaustive.

Type of risk		Market	Operational	Business	Legal
Definition		Involve market- and trade-related factors that impact business assets and liabilities	Involve factors that impact a firm's internal operations	Are a result of emerging societal, economic and political trends that impact the firm's strategic business objectives	Arise from current and future regulations, standards and protocols
% circular inflow	Opportunity	Tech: cost advantage non-virgin resources Bio: premium for certified bio-based resources	New partnerships Tech: set-up take-back and collection schemes in value chain Bio: food waste reduction program within value chain	Disruptive new technologies Tech: tracking and tracing for return logistics Bio: increased technology for supply chain transparency	Tech: subsidies for secondary material use Bio: subsidies for renewable (certified resources)
	Risk	Resource price volatility Tech: scarcity of certain inorganic materials with specific functionality (i.e., critical minerals) Bio: scarcity of renewable resources – i.e., competition in land use between food crops and crops for renewable energy	Supply chain failures	Changing consumer demand Tech: growing demand for second-hand products Bio: growing demand for plant-based diets	Fines or lawsuits Tech: eco-design directives requiring a minimum % recycled content Bio: new regulations and policies for bio-based materials

% circular outflow	**Opportunity**	Tech: valorizing waste as secondary resource Bio: valorizing waste to distill bio-nutrients	Attracting and retaining talent	Tech: New business models such as product as a service or sell and buy back Bio: higher valorization and avoidance of valuable food loss	Governmental stimulation of circular solutions Tech: subsidies and incentives for business model innovation Bio: subsidies and incentives for high valorization of biodegradable flows
	Risk	Trade bans (on resources & waste) Tech: i.e., Basel convention for border crossing of electronics Bio: discrimination between edible and non-edible waste stream handling	Internal process failures	Changing consumer demand Tech: right to repair movement Bio: consumer-driven initiatives to combat food waste	Extended producer responsibility Tech: mandatory contribution to open-loop collection and recycling schemes Bio: new regulations or policies for avoidance of food loss
% water circularity	**Opportunity**	Trading water rights in states with formal water markets	Reliability of water inflow with consistent flow and pressure	Advantage over competitors	Potential for more secure water rights due to demonstrable sustainable management
	Risk	Dependency on low water prices, which can rise when scarcity increases	Water shortages disrupting operations and unforeseen mitigation cost	Local reputation and loss of social license to operate Local activism	Upcoming tightening of regulations with rising water scarcity
% renewable energy	**Opportunity**	Abundance of renewable resources	New partnerships	Decreasing cost of renewables	Renewable energy subsidies
	Risk	Resource scarcity	Worker safety issues	Increasing fossil energy prices	More stringent laws
% critical materials	**Opportunity**	Closing the loop	Job creation	Disruptive new technologies	(New) government policies
	Risk	Lower investor interest	Worker safety issues	Changing consumer demand	Sourcing rules and regulations
CTI revenue	**Opportunity**	More resilient and steady cash flows from portfolio	Drive internal competition across business	Brand equity and reputation benefits	Preparedness for reporting and disclosure
	Risk	Lack of insights responding to investor inquiries	Avoidable layoffs due to failure to improve portfolio	Competitive disadvantage due to inaction	Upcoming regulations on more linear products

Actual lifetime	Opportunity	Reduced VAT rate for repaired/ refurbished products Market expansion opportunities Increase of product portfolio Reduction of manufacturing costs Reduction of sourcing costs	Identification of design improvements for future products Work with higher added value materials Reduction of waste generation	Customer fidelity (e.g., product as a service) Supply chain security	Digital product passport Repairability index/ scoring system (e.g., Ifixit) Green procurement to require min. 25% refurbished and second-hand products
	Risk	Ensure availability of technical service and supply/spare parts after warranty expires (e.g., ecoinvent requires availability of spare parts of 10 years for cold and wet appliances)	Lack of take-back, technical support or repair infrastructure	Consumer concern for prioritizing products from companies that address key value chain issues	Legislation against premature or planned obsolescence Legislation to promote minimum durability criteria, extended product responsibility Right to repair
GHG impact	Opportunity	Better positioning by using less carbon intensive materials Better positioning by using less carbon intensive materials	Better positioning by using less carbon intensive materials	Providing alternatives with a lower carbon footprint	Benefits for products offerings with lower carbon footprint
	Risk	Increased demand for circular recovery of materials due to end of life GHG scope 3 savings commitments Increased demand for circular recovery of materials due to end of life GHG Scope 3 savings commitments	Factoring of carbon price into procurement of virgin materials	Providing alternatives with a lower carbon footprint Ability to meet consumer demand for lower impact products	Ability to meet waste GHG reporting requirements Ability to meet waste GHG reporting requirements
Nature impact	Opportunity	Access to consumer premiums and impact investment for reduced nature-related damage.	Reduce or substitute dependencies with highest nature-related risks. Contribute to sector-level conservation and restoration practices in sourcing landscapes.	Provide alternatives with a lower impact on biodiversity to (new) clients.	Advance preparation for compliance with new regulatory frameworks for biodiversity, such as the EU's Corporate Sustainability Reporting Directive.
	Risk	Failure to meet increased demand for materials that are sustainably-sourced, in particular for materials that are deforestation & conversion free.	Nature-related risks could threaten the production of key commodities across a supply change. For example, land-use change past certain ecological thresholds can affect water quantity, regional climate, pollination, and yields.	Inability to meet consumer demand for sustainably-sourced products. Reputational risk / opposition from local communities, indigenous groups and environmental organizations.	Failure to anticipate or comply with existing regulations could limit access to certain markets or financing, create financial and legal liabilities.

LINEAR RISK ASSESSMENT AND PRIORITIZATION

We recommend that companies formulate and prioritize actions in light of their impact on identified linear risks in different scenarios. This process can be as simple (half-day workshop with experts in the company to go through the steps) or as elaborate (days to weeks with detailed data for thorough analysis) as desired, depending on the needs and resources of the company. Either way, we recommend the following steps:

Scenario analysis

Outline circular economy scenarios:

1. No regulatory or market pressure
2. Diverse national or regional regulatory pressure
3. Strong global market and regulatory pressure

Establish risk severity

Establish the severity of linear risks:

1. Threat prioritization
2. Vulnerability prioritization

Define and assess action roadmaps

Define and assess action roadmaps based on:

1. Ability to mitigate linear risks
2. Benefits from circular opportunities

1. Scenario analysis

Similar to climate scenarios, there are endless scenarios for how the transition to a circular economy may develop for each sector. By researching and forecasting alternative scenarios, companies can take into consideration future developments in the formulation and prioritization of actions.

At this stage, a company should investigate possible future scenarios and develop an understanding of how these may affect the business. Companies may apply a time-bound approach to understand developments in each possible scenario (e.g., today, in 5 years, in 10 years). In this exercise, companies should include:

- **No regulatory or market pressure:** How will the company be affected if the playing field remains the same?
- **Diverse national or regional regulatory pressure:** How will national or regional targets affect the business of a company in the future?
- **Strong global market and regulatory pressure:** How will robust combined global trends (technology, markets, regulation) affect the business of the company?

In each of these scenarios, companies can decide which factors to use to assess the impact on the business. Suggestions for monetary, quantitative or qualitative factors are:

- Costs
- Revenues (including CTI revenue)
- Profit
- Customer relationships
- Employee relationships
- Supply chain collaboration

NATIONAL OR INTERNATIONAL LEVEL TARGETS SCENARIO

Various countries and international authorities, like the European Commission, have set goals and targets to adopt a circular economy. Policy packages describe (potential) policy measures over time. It is relevant to describe how those would influence the four risk categories and how it relates to the targets formulated at the company level.

POLICIES

For an overview of circular economy policies, see our policy brief Driving the Transition to a Circular Economy.

WHAT IS A SCENARIO?

A scenario describes a path of development leading to a particular outcome. Scenarios are not intended to represent a full description of the future, but rather to highlight central elements of a possible future and to draw attention to the key factors that will drive future developments. It is important to remember that scenarios are hypothetical constructs; they are not forecasts or predictions, nor are they sensitivity analyses. Scenario analysis is a tool to enhance critical strategic thinking. A key feature of scenarios is that they should challenge conventional wisdom about the future. In a world of uncertainty, scenarios are intended to explore alternatives that may significantly alter the basis for "business-as-usual" assumptions. (**Source:** Task Force on Climate-related Financial Disclosures 2017 report on The Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities.)

In addition to scenario analysis, other tools might be useful, including expert input, forecasting and valuation and other environmental, social and governance (ESG)-specific tools. The COSO Enterprise Risk Management (ERM) framework elaborates on all of these.[60]

2. Establish risk severity: Threat and vulnerability assessment

In this step, companies use the information gathered from the scenario analysis to rank and prioritize linear risks. Common criteria for risk prioritization are severity of adverse impact and likelihood; however, relying on these factors alone might limit the accuracy of the prioritization. Therefore, we suggest using two more-elaborate criteria defined by the COSO ERM framework:

- **Threat** (inherent risk), where the impact (the consequences) and the velocity or speed of onset (the speed at which risk impacts an entity) determine the magnitude of the threat.

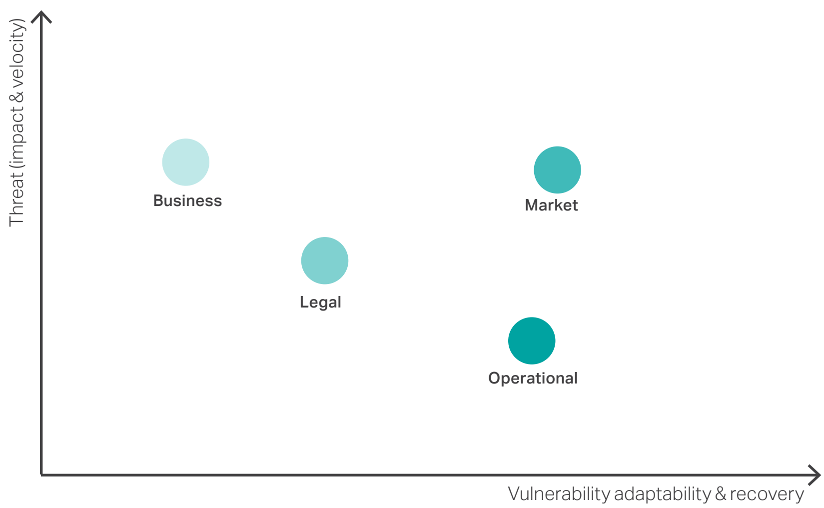
- **Vulnerability** (residual risk), defined in terms of adaptability and recovery. The magnitude of the vulnerability depends on adaptability (the capacity of an entity to adapt and respond to risks) and recovery (the capacity of an entity to return to tolerance).

Companies can visualize the above-mentioned risk factors in one overview to enable formulation of potential actions and final prioritization. Illustrates the threat of a hypothetical company's linear risk (y-axis) versus vulnerability (x-axis).

The graph only shows the main risk categories for demonstration purposes. However, it can be more specific and include all linear risk subcategories, including resource scarcity and changing consumer demands.

This visualization can help prioritize which risk to address first. Based on this prioritization, and in combination with the insights obtained during the analysis phase, companies can plan the roll out and next steps.

Figure 25: Plotting the risks



COSO

The Committee of Sponsoring Organizations of the Treadway Commission (COSO) is a joint initiative bringing together five private sector organizations. It is dedicated to providing thought leadership through the development of frameworks and guidance on enterprise risk management, internal control and fraud deterrence.

Source: www.coso.org

3. Define potential action roadmaps

In this step, companies define and assess potential action roadmaps. The purpose of this step is to use the insights gathered on circular economy scenarios outlined in Step 1 and relevant linear risks explored in Step 2 to describe how the business of the company may develop in the future.

We recommend starting by evaluating a "business as usual" (BAU) situation that describes how the company's business will develop without taking additional action for circularity.

Afterward, companies can use the BAU situation as a baseline and to outline potential action roadmaps in which different actions are taken to:

- Mitigate the identified linear risks
- Unlock potential benefits from circular opportunities.

Companies can carry out the description of how each action roadmap changes the future of the company using a text-based system, meaning similar to writing a story, or can visualize it graphically, for example as a timeline with different future events. We recommend using the quantitative and qualitative factors defined in Step 1 in order to highlight the effects achieved in each action roadmap.

LINKING CIRCULAR SOLUTIONS TO ACTION ROADMAPS

In the previous steps, companies identify:

1. Material flows with improvement potential (Step 5)
2. Action roadmaps to address linear risks and circular opportunities.

Companies should consider both aspects as they assess the most appropriate circular solutions at a material flow level. At this stage, companies should engage with stakeholders from different business processes, (e.g., from product development, supply chain, production, business models or end-of-life operations), to analyze how proposed solutions will affect corresponding material flows and indicators' results in the CTI framework.

Some recognized circular solutions to improve performance for indicators included in the CTI framework are:

For inflow

- Replace current linear inflow with non-virgin alternatives
- Replace current linear inflow with renewable alternatives
- Replace non-renewable bio-based resources with renewable alternatives (for example through certification for sustainably managed bio-based resources)
- Reduce resource use through light-weighting of products
- Reduce resource use through use optimization, digitalization, replacing physical products with services (called "servitization" in some sectors), durability, etc.
- Reduce resource use through optimizing nutrient consumption (i.e., avoiding food waste and replacing nutrients/protein with less resource-intensive alternatives)

For recovery potential

- Redesign to incorporate, among others, modular design, design for disassembly, high recyclability by using mono-materials (technical cycle) and/or biodegradability and non-toxicity (biological cycle)

For actual recovery

- Increase actual recovery by selling a product as a service or instituting pay per use (technical cycle)
- Increase actual recovery through buy-back/take-back schemes (technical cycle)
- Increase the actual recovery through value chain collaboration and partnerships for collection and recovery programs
- Increase biodegradable outflow that is actually consumed (i.e., by avoiding food waste or high valorization) (biological cycle)

REPLACING VIRGIN INFLOW WITH SECONDARY OR RENEWABLE INFLOW

Replacing virgin inflow with secondary inflow or renewable inflow reduces linear inflow mass. If the price of the product remains the same, the performance on the indicator improves.

LIGHT-WEIGHTING A PRODUCT

Light-weighting a product should not affect the price of the product and therefore will not impact company revenue. If the material removed from the product (partly) consists of linear inflow, the linear inflow will decrease. This results in a higher circular material productivity.

DIGITALIZATION FROM HARDWARE TO SOFTWARE

If software is offered in addition to hardware, the absolute revenue grows. The software can provide additional functionality to the hardware or can replace part or all of the hardware. If this is (partly) made from linear inflow, the linear inflow will decrease. This results in higher circular material productivity.

For water circularity

- Replace linear water sources with circular alternatives like third-party water or reused wastewater from the facility's own processes where possible increase treatment of wastewater (either onsite or through a wastewater treatment facility) to regional regulatory quality levels before discharge into the local watershed
- Find alternatives to minimize transportation of water out of the local watershed (either through shipping of product, evaporation or discharge in the sea)

For actual lifetime

- Design products for durability, reusability, upgradability and repairability
- Implement business models that incentivize longer useful lives (e.g., product as a service)
- Provide accessible technical service and supply/spare parts for products beyond warranty
- Limit software obsolescence to improve durability of electronics

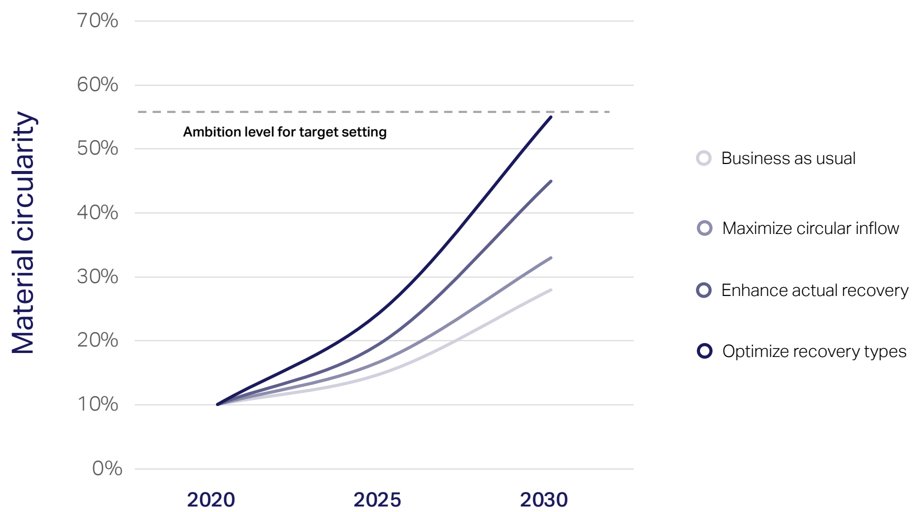
For CTI revenue

- Improve product portfolio circularity by implementing solutions highlighted under "for inflow", "for recovery potential" and "for actual recovery"
- Drive increased sales in more circular products (compares to less circular products)

This list is not exhaustive and could grow over time, but it is a good starting point to look at possible solutions to consider. The examples on this and the following page illustrate what some of these solutions could look like.

By making assumptions on the changes in material flows, companies can calculate the effects on material circularity performance in each course of action. In this way, it is possible to identify improvement potentials in relation to the BAU scenario (see Figure 26).[61] Additionally, companies can use the results to define ambition levels as part of their strategic target setting.

Figure 26: Comparing action roadmaps to improve material circularity performance



TRANSITION TO PAY-PER-USE MODEL

In the transition from a product sales model to a pay-per-use model, circular material productivity increases as the business model will enable the cycling of products and payment as a service (therefore the linear inflow goes down relative to revenue generated).

SELLING MORE DURABLE PRODUCTS

The assumption is that products made at a higher quality are more durable, thus the price per product can increase. Therefore, the relative revenue in relation to linear material use will improve if linear material use remains similar.

CIRCULAR OPPORTUNITIES: EVALUATE THE BUSINESS CASE

At this stage in the process, companies have more clarity about:

- The material flows with improvement potential (Step 5)
- Prioritized action roadmaps to address linear risks and circular opportunities
- The circular solutions and their effects on material circularity performance

Evaluating the business case can help, either by selecting potential options or by verifying their expected business outcomes. Our 8 business cases for the circular economy report emphasizes that circular business practices can accelerate growth, enhance competitiveness and mitigate risk. To seize circular opportunities, it is necessary to demonstrate the business case.

In principle, the circular business case is like any other business case; but there is potential to overlook some circular business case characteristics when applying business-as-usual. Therefore, we list some relevant considerations when evaluating the business case for circularity below.

1. Evaluate as any other business case

The first step is to assess it like any other business case. If there is already a clear case, there may be no need to demonstrate the circular added value.

2. Consider potential cost savings in a circular business case

- Savings can be related to the inflow by replacing linear (virgin non-renewable) by circular inflow (either renewable or non-virgin).

cost savings = costs 100% linear inflow – costs current inflow

potential cost savings = costs current inflow – costs 100% circular inflow

- Savings can be related to better client retention and acquisition (either by the "green image" or by fostering long-term relationships in product-as-a-service or buy-back/take-back contracts), which can reduce marketing costs.
- Savings can be related to better retention and attraction of talented employees (driven by the "purpose" of circular business).
- Savings can be related to the avoidance of losses (for example nutrient loss related to food waste for the biological cycle or reusing rest streams for the technical cycle).
- Savings can be related to reduced waste management costs as resources are recovered and reused.

3. Identify increases in revenues

- New customers attracted by circularity, convenience and/or sustainability.
- New segments because of lower initial investment for a service than a product (pay-per-use model) by clients.
- New revenues related to high valorization of waste streams and (by-) products.

4. Anticipate and respond to growing investor interest

As investors increasingly become aware of circular economy opportunities, companies should proactively communicate with investors about their commitments to the circular economy and be prepared to demonstrate performance when approached by investors.

5. Account for the long(er) term perspective

Product-as-a-service or trade-in offers are based on longer term service contracts or buy-back/take-back offers. Adopting these business models may stabilize profits over time and improve future cash flow predictability.

- By maintaining ownership of the products or regaining access, the company secures future supply and hedges against future resource inflow price volatility.

The societal shift to a circular economy may create future changes in costs savings, profitability and legal requirements (see also the section on scenario planning).

Sanity check:

To avoid adversely impacting other externalities when at scale, it is important to ensure that the company avoids tunnel vision in pursuing circular ambitions and instead accounts for the broader sustainable impacts. Complete the picture by complementing circular performance assessments with environmental and social life cycle assessments (LCAs) and other tools. LCAs and other product-related indicators remain key tools to assess or compare circularity between different products.

Always implement these considering the local context to account for all intermediary steps and to identify the most appropriate solutions. This will ensure that the company recognizes any potential trade-offs that may present themselves in analyzing circular strategies across different environmental and social impacts and dependencies.

⑦ Apply
Plan and act

After analyzing the results, prioritizing the risks and opportunities, assessing the circular solutions and defining the business case, the next step is to formulate targets for improvement and execute related actions.

Formulate targets

Based on the analysis, the potential opportunity for improvement has become apparent. In addition, the prioritize phase has identified the risk and opportunities to address. When combined, this information provides relevant evidence to formulate SMART targets.

Roll out actions

It is necessary to create actions in order to achieve the targets. Although it is up to the company to further define the specific actions per target, the following is some guidance on elements to consider.

Define what needs to happen

The target gives direction on what needs to happen. As described in the analysis section and in the first column of the tables below, there are high-level examples of possible directions to take. It is up to the company to further formulate specific actions based on the nature of the company and the outcomes of the analysis.

Define when it needs to happen

Companies should set up an action plan through back casting. With the time-bound target in mind, companies can roll out intermediate targets and actions based on a roadmap. It is important to define the timelines within the roadmap to ensure the alignment of assessment cycles with the intermediate targets.

Define who needs to take action

To ensure action, it is necessary to identify an owner to drive action. The tables below list the possible actions from the analyze phase, with the relevant departments internally, the external parties to consider and considerations to take into account when executing the action.

Assess the actions and progress on formulated targets

It is important to recognize that this phase is not the final phase of the Circular Transition Indicator framework. As visualized in Figure 27, the process steps follow each other in a cycle and this phase will feed into the scoping phase to start the next assessment and monitor improvement on the targets resulting from the actions executed in the apply phase.

Table 11 provides some additional insights into elements for consideration when planning and rolling out some of the circular solutions as discussed earlier.

SMART TARGETS

Specific: focus on one element of the indicator at a time (formulate separate targets for the % non-virgin inflow and the % renewable inflow)

Measurable: focus on quantitative targets captured within the framework

Ambitious yet achievable: based on the controllability assessed in the planning phase, focus on targets that largely depend on internal factors to ensure it is achievable

Relevant: focus targets on the most relevant areas based on the analysis (i.e., the largest flows or the most critical materials)

Time-bound: define deadlines for meeting targets and plan the assessment cycle accordingly

Figure 27: The process cycle

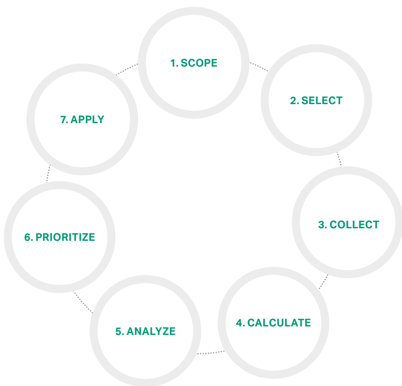


Table 11: Elements for consideration when planning and rolling out circular solutions

Departments to involve	Other parties to consider	Considerations when executing	Example target	Example action
Reduce linear inflow by replacing it with renewable inflow				
Sustainability Procurement Product design Product management R&D	Suppliers Certification bodies	Suppliers	Launch a new fashion line using natural materials by 2023	Explore how certificates consider sustainability and land use and explore the functionality of certified materials for purpose
Reduce linear inflow by replacing it with secondary inflow				
Sustainability Procurement Product design Product management R&D	Suppliers	Sustainability Technical feasibility Acceptance by customer Functionality	Product category X should contain 40% recycled content by 2025	Discuss technical feasibility and availability with supplier Switch supplier if needed
Sustainability Product design Product management R&D	Clients	Functionality Acceptance by the customer	Double the lifetime use of product category X by 2025	Discuss technical feasibility with design department Research bottlenecks for product use among consumers (i.e., technical limitations, fashion, status, etc.)
Increase recovery potential by optimizing product design (for modularity, disassembly, mono-material's biodegradability)				
Sustainability Product design Service and maintenance Product management R&D	Clients Suppliers	Technical feasibility Economic viability	60% of bottles produced consist of mono-materials by 2022 20% less in food waste residues by optimizing packaging by 2025	Change supplier Set up research with supplier
Sustainability Product design R&D	Clients Suppliers	Technical feasibility Economic viability	Ensure the replacing of all technical materials in the "hybrid product" with biodegradable alternatives	Request supplier overview of biodegradable (according to OECD) alternatives
Increase actual recovery by maintaining ownership or buy-back/take-back schemes				
Sustainability Product design Sales Account management Customer relations Service and maintenance Legal Product management	Clients Financiers	Financial implications, e.g., on balance sheet and cash flow Legal implications	30% of revenues from high-value assets should come from pay-per-use models by 2025	Pilot with a supplier for return logistics Market research to understand client needs and barriers for the new model

Increase actual recovery by setting up take-back/buy-back or recovery schemes with third parties in the value chain				
Sustainability Product design Sales Account management Customer relations Product Management R&D	Clients Suppliers	Collaboration forms with other parties	Set up a take-back or buy-back scheme for all newly sold phones by 2023	Set up an agreement with a refurbishment company
Sustainability Account management Customer relations Marketing	Clients	Collaboration with other parties	Set up a program with retailers to give discounts on almost expiring food products to increase high valorization by consumption	Explore collaboration partners for such a program
Increase actual recovery by investing in and advocacy for public schemes				
Sustainability Public relations	Customers Public authorities	Achievable influence and impact	Support public scheme advocacy in 95% of offset markets by 2025	Join forces with peers on advocacy
Increase actual recovery by investing in and advocacy for public schemes				
Utilities/ engineering, Procurement, Product quality, Manufacturing Facility management, Public affairs, Government affairs	Local stakeholder community in watershed Municipal wastewater service provider Universities/ research institutions Civil society Regulators	Acceptance by customer (flavor, safety) Watershed water balance, Regulatory permit compliance		

Annex

Annex I — Nature impact: Assessment of mine site extent

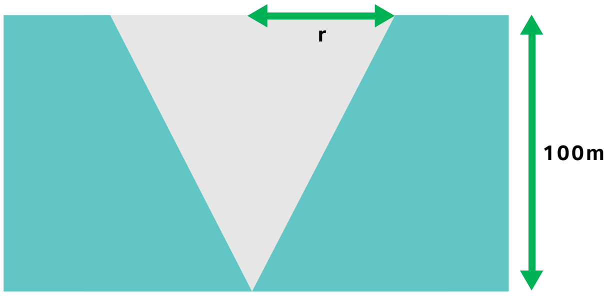
This technical annex aims to provide the formula needed to assess the extent of land required for a mass of a mineral commodity (Mm) from a mining site without knowing the yield of the site. It is based on a geometric approach and covers two types of mine sites (Figure 28)

- Open pit, a surface mining technique with conical shape as visible on Figure 28a;
- Strip mine, a surface mining technique with cuboid shape as visible on Figure 28b;

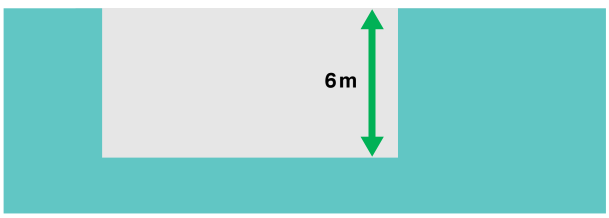
Underground mines are always assumed to have a very small extent, since a very small area of land is converted for the mine pit, since mining takes place below the surface.

Figure 28: Schematic representation of the mines and dimensions used for the calculation

a) Open pit scheme



b) Strip mine



To assess the extent based on volume and geometry, it is first necessary to estimate the total volume of rock extracted from the mine (Ve), as per the following steps:

1. Convert the mass of mineral (Mm) into a mass of total rock (Mr), as per published rock-to-metal ratios (R), where Mr = R x Mm
   These ratios provide a simple estimate of the total mass of material extracted from the ground per unit mass of metal required.
2. Convert the mass of rock into a volume, based on the formula Ve = Mr / ρr, where ρr is the estimated density of the mined rock

As such:

$$V_e = \frac{R \times Mm}{\rho r}$$

Once the volume has been estimated, it is possible to use simple mine geometry assumptions (Figure 28) to estimate the extent of land converted for mineral extraction as per:

$$\text{Extent} = \frac{3v_e}{100} \quad \text{for an open pit mine}$$

$$\text{Extent} = \frac{v_e}{6} \quad \text{for a strip mine}$$

In the case of aluminum, the estimated rock-to-metal ratio is 7, while the density of bauxite is 1,100– 2,000 kg/m^3. Therefore the extracted volume for 15 million kg of aluminum can be estimated as Ve = 15,000 x 7 / 1,100 = 95 m^3, and the estimated attributable extent for an open pit mine is 3 x 95 / 100 = 2.85m^2.

Once the extent of the mine is assessed, extent multipliers should be added to take into account associated indirect impacts of infrastructure. The can be approximated to around 15x the pit area, where:

- Any associated infrastructure - **2x pit area**
- The land area for any waste rocks – **1.43x pit area**
- The area required for storage of mine tailings – **10x pit area**

These assumed amounts are taken from the GBS mining critical review document. More precise data could be used where available. Therefore, the estimated attributable extent for sourcing 15 million kg of aluminum from an open strip mine is 42.75m^2

Choice of ecosystem condition metrics

The extent, condition and significance framework is flexible with regards to the selection of condition metric. There are many indicators against which a condition metric can be assessed. For example, condition metrics should ideally be scientifically robust (having undergone peer-review is an indicator of this), practical to use, simple to interpret, have global coverage, and be based on transparent and regularly updated data. Alignment with regulatory and voluntary reporting frameworks is also a bonus. Our framework proposes the Mean Species Abundance (MSA), which is based on the GLOBIO model, as an example. Many other ecosystem condition measures could also be used – for example Potentially Disappeared Fraction, Proportion of Land Degraded, Marine Cumulative Human Impacts, Ecoregion Intactness Index, Ecosystem Integrity Index, Ecosystem Health Index, and Ecosystem Area Index. MSA aligns well with the criteria described above, but other ecosystem condition metrics listed here could also be used instead. They are all highly correlated with each other so this would not substantially change the results.

The Ecosystem Integrity Index (EII) has been proposed for the draft SBTN Land Step 3 methods. We did not include it in CTI because it has not undergone peer review and the underlying data and tools are not available yet. We expect this to change by mid-2023 and are potentially open to including EII as a condition metric pending review of the final product.

How does this help companies align with TNFD?

Companies are required to disclose the metrics used by the organization to assess and manage impacts on nature, including "Whether and how the organization assesses the condition and extent of the ecosystems in priority locations, with reference to the tools, data platforms, indicators and metrics used, and the science-basis for the link to response to nature-related risks and opportunities." Find more information on TNFD. The extent and condition components of the framework address this and STAR (significance) can be used for prioritization.

Is significance included in SBTN?

Yes, SBTN Step 2 guidance (p. 95) requires companies to prioritize sites according to general State of Nature indicator (SoNG) and recommends using the threat abatement component of the Species Threat Abatement and Restoration metric (START) which we have incorporated into the Significance component of the CTI Nature impact indicator.

CTI glossary

% material circularity
The weighted average of the % circular inflow and % circular outflow for a given product (group or portfolio), business unit or company.

Biodegradable outflow
Outflow of material or substance that microorganisms can decompose and that degrades to organic molecules that living systems can use further,[62] for example via composting and anaerobic digestion.
A product can only be considered biodegradable if its levels of toxins or hazardous substances fall within recognized thresholds (e.g., Cradle to Cradle Certified Products Program, DRAFT v4 Restricted Substances List (RSL)). Companies can refer to existing testing standards on biodegradability and compostability such as the OECD, the International Standards Organization (ISO) or the Royal Netherlands Standards Institute (NEN) among others.

By-products
Unintended but inevitable additional material stream of material processing that is not the intended main product.

Co-processing
The simultaneous use of residual waste as a source of mineral resources (material recycling) and as a source of energy to substitute fossil fuels in a single industrial process. During co-processing the mineral part of the waste replaces primary materials (such as limestone, clay or iron) and the combustible part provides the energy needed for the industrial process (e.g., cement production).

Circular economy principles

- Design out waste and pollution
- Keep products and materials in use
- Regenerate natural systems

Circular inflow

Inflow that is:

- Renewable inflow (see definition) and used at a rate in line with natural cycles of renewability

OR

- Non-virgin

Circular outflow

Outflow that is:

- Designed and treated in a manner that ensures products and materials have a full recovery potential and extend their economic lifetime after their technical lifetime

AND

- Demonstrably recovered

Circular performance
The multidimensional results of a product (group), business unit, including % circularity (% circular inflow and % circular outflow) and at least one other CTI indicator. This indicator may be from any of the three modules.

CTI revenue
The revenue generated by a product (group or portfolio), business unit or company multiplied by its % circularity

Company boundary
Physical or administrative perimeter of the organization, consistent in scope with financial and sustainable reporting

Downcycling
Recycling "something in such a way that the resulting product is of lower (economic) value than the original item."[63]
It indicates a loss of the material/product's original characteristics that precludes use in a similar function to its previous cycle (functional equivalence). Downcycling is usually used to describe a product's material properties, their level of degradation or, in the case of metals, if they have become impure, which leads to a loss of economic value.[64]

Durability
Durability means the ability of a product to function as required, under specified conditions of use, maintenance and repair, until a limiting event prevents its functioning.

Functional equivalence
"The state or property of being equivalent" (or equal) in function.[65]

In the context of CTI, this defines an outflow (a product, product part, waste stream, etc.) designed so that it is technically feasible and economically viable to bring it back to inflow (as a material, product part, etc.) preserving a similar function to its previous cycle. For example, it is possible to recycle the plastics used in mobile phones for kitchen appliances because properties like strength and esthetics are equivalent.

Inflow
Resources that enter the company, including materials, parts or products (depending on a company's position within the supply chain). Not included are water and energy, which are part of the specific water and energy indicators.

Land-use change
Land-use change is the conversion of natural areas into human-dominated landscapes, caused by activities such as urbanization, deforestation, agriculture and infrastructure development. This process is a key driver of biodiversity loss.

Addressing land-use change is vital to preserving biodiversity and ensuring sustainable development.

Linear inflow
Virgin, non-renewable resources

Linear outflow
Outflow that is not classifiable as circular. This means that the outflow:

- Is not circular in design/ consists of materials treated in a manner that they have no recovery potential

OR

- Neither demonstrably recovered nor flowing back into the economy.

Linear risk
The exposure to the effects of linear business practices – use scarce and non-renewable resources, prioritize sales of new products, fail to collaborate and fail to innovate or adapt – which will negatively impact a company's license to operate.[66]

Non-virgin inflow
Inflow previously used (secondary), e.g., recycled materials, second-hand products or refurbished parts.

Outflow
Material flows that leave the company, including materials, parts, products, by-products and waste streams (depending on a company's position within the supply chain).

Recovery
The technically feasible and economically viable recovery of nutrients, compounds, materials, parts, components or even products (depending on the organization) at the same level of functional equivalence through reuse, repair, refurbishment, repurposing, remanufacturing, recycling or biodegrading.

This excludes energy recovery from waste and any biological cycle waste that does not satisfy all criteria as outlined on p. 45.

Recovery types
The different forms of material recovery, such as (in order of the recirculation loops in the Ellen Macarthur Foundation's Circular Economy System Diagram[67] or butterfly diagram):

Reuse
To extend a product's lifetime beyond its intentional designed life span, without changes made to the product or its functionality.

Repair
To extend a product's lifetime by restoring it after breakage or tearing, without changes made to the product or its functionality.

Refurbish
To extend a product's lifetime by large repair, potentially with replacement of parts, without changes made to the product's functionality.

Remanufacture
To disassemble a product to the component level and reassemble (replacing components where necessary) to as-new condition with possible changes made to the functionality of the product.

Recycle
To reduce a product back to its material level, thereby allowing the use of those materials in new products.

Biodegrade
Microbial (bacteria and fungi) breakdown of organic matter in the presence of oxygen to produce soil with high organic (humus) content.

Regenerative
To have the ability to restore material resources and improve ecosystem health to ensure productivity and other benefits (e.g., carbon capture, biodiversity, and other ecosystem services). Note that regeneration goes beyond retaining the status quo of natural systems that may already have degraded from their initial state.[68]

Renewable inflow
Sustainably managed resources, most often demonstrated by internationally recognized certification schemes like the Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification (PEFC), Roundtable on Sustainable Palm Oil (RSPO), etc.[69] that, after extraction, return to their previous stock levels by natural growth or replenishment processes at a rate in line with use cycles. Therefore, they are replenished/regrown at a faster rate than harvested/extracted.[70]

Virgin inflow
Inflow not previously used or consumed (primary).

Endnotes

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[12] Definition from United Nations Environment Programme (2017). *The Long View: Exploring Product Lifetime Extension* (p. 14). Retrieved from: https://wedocs.unep.org/20.500.11822/22394.

[13] See European Commission (2022). "Proposal for a regulation on Ecodesign for Sustainable Products" (p. 45). Retrieved from: https://environment.ec.europa.eu/publications/proposal-ecodesign-sustainable-products-regulation_en.

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[15] See European Commission (2022). "Proposal for a regulation on Ecodesign for Sustainable Products" (p. 100). Retrieved from: https://environment.ec.europa.eu/publications/proposal-ecodesign-sustainable-products-regulation_en.

[16] For more context, refer to *WBCSD Vision 2050: Time to Transform.*

[17] The system model "Allocation, cut-off by classification" – or the cut-off system model – is based on the recycled content – or cut-off – approach. In this system model, wastes are the producer's responsibility ("polluter pays"), and there is an incentive to use recyclable products that are available burden-free (cut-off). Source: ecoinvent (n.d.). "Database – System Models - Allocation cut-off by classification". Retrieved from https://ecoinvent.org/the-ecoinvent-database/system-models/#!/allocation-cut-off.

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[30] Using the company's own or supplier-specific data to determine.

[31] If a company's own or supplier-specific data is not available, companies may use inventory life-cycle databases to determine the emissions.

[32] See Table S4 in Nassar, N.T., Lederer, G.W., Brainard, J.L., Padilla, A.J., & Lessard, J.D. (2022). SUPPORTING INFORMATION for Rock-to-metal ratio: a foundational metric for understanding mine wastes. Retrieved from: https://pubs.acs.org/doi/suppl/10.1021/acs.est.1c07875/suppl_file/es1c07875_si_001.pdf.

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ATTRIBUTION

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ABOUT THE CIRCULAR TRANSITION INDICATORS PROJECT

In recent years, the circular economy has increasingly appeared as the new model to pursue sustainable economic growth. For companies to be able to assess their circular performance, they require consistent measurement processes and metrics. To address this need, jointly with our members and stakeholders, we have developed a universal framework to measure circularity. The Circular Transition Indicators (CTI) is a transparent, objective and evolving framework that can be applied to businesses of all industries, sizes, value chain positions and geographies. Explore more at the following link: https://www.wbcsd.org/Programs/Circular-Economy/Metrics-Measurement

ABOUT WBCSD

WBCSD is the premier global, CEO-led community of over 200 of the world's leading sustainable businesses working collectively to accelerate the system transformations needed for a net zero, nature positive, and more equitable future.

We do this by engaging executives and sustainability leaders from business and elsewhere to share practical insights on the obstacles and opportunities we currently face in tackling the integrated climate, nature and inequality sustainability challenge; by co-developing "how-to" CEO-guides from these insights; by providing science-based target guidance including standards and protocols; and by developing tools and platforms to help leading businesses in sustainability drive integrated actions to tackle climate, nature and inequality challenges across sectors and geographical regions.

Our member companies come from all business sectors and all major economies, representing a combined revenue of more than USD $8.5 trillion and 19 million employees. Our global network of almost 70 national business councils gives our members unparalleled reach across the globe. Since 1995, WBCSD has been uniquely positioned to work with member companies along and across value chains to deliver impactful business solutions to the most challenging sustainability issues.

Together, we are the leading voice of business for sustainability, united by our vision of a world in which 9+ billion people are living well, within planetary boundaries, by mid-century.

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