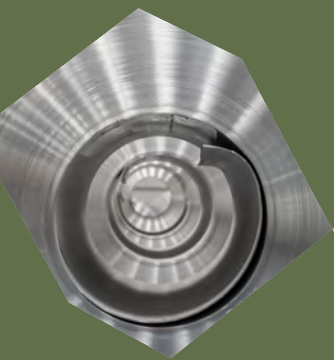
Circular Transition *Indicators (CTI)*

→ Sector guidance — Electronic devices



World Business Council *for Sustainable Development*

CTI

Contents

Thank you to the companies and organizations that contributed to this guidance:

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Foreword

Companies in the electronics sector are intensifying their efforts in transitioning to circular business models in response to evolving consumer needs, materials scarcity, regulatory pressures, and electronic waste (e-waste) mounting globally, along with environmental and social costs.

The adoption of a standardized methodology can help businesses measure and manage progress in their transition, and align the way in which companies measure success, steer improvement, collaborate with stakeholders across the value chain and prepare to communicate progress, both internally and externally.

We propose a dedicated methodology based on globally recognized circularity performance measurement metrics, developed in close consultation with leading companies in the sector, and facilitated by the Circular Electronics Partnership (CEP).

The Circular Transition Indicators (CTI) are a sector-agnostic framework developed by WBCSD with a proven track record across industry sectors globally in companies leading in sustainability. **CTI provides a transparent, quantitative, and comparable framework for measuring circular performance. It helps companies evaluate risks, identify effective actions to enhance circularity and understand the impact of their circularity strategies on their sustainability goals.** It is a comprehensive and flexible circularity measurement framework that is publicly available to companies from all sectors and of all sizes.

Through this guidance we propose a tailored approach that addresses the electronics value chain challenges and specificities. Working with these metrics can help businesses drive change by:

→ Defining circularity roadmaps and measuring progress based on credible quantitative baselines;

→ Driving strategic decision-making based on the benefits and trade-offs of different circularity strategies;

→ Providing a clear view of sustainability impacts – whether on climate or nature – and underscoring the tangible outcomes of circularity initiatives;

→ Promoting accountability and transparency with a foundation in quantitative measures.

We've structured the report based on generic activities in the electronics value chain, spanning from raw material extraction to recycling to support all value chain players build baselines, identify and test strategies with the highest impact, and monitor improvements.

We invite all companies in the electronics value chain to adopt CTI and this guidance as the framework for circular performance measurement in the industry. Doing so supports companies by speaking a common language, fostering collaboration across the sector, ensuring comparability in data, and joining value chain efforts for a more circular electronics industry.

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Executive *Summary*

Executive Summary

Electronic devices have become a regular feature in lives worldwide, helping people and businesses stay connected and enabling them to do more and more every day.

Although such devices deliver value for both people and businesses, **companies still largely produce them and bring them to market based on a conventional "linear economy" approach dependent on the extraction of raw materials, high energy use in manufacturing and a design focusing on a short lifespan and early disposal.**

The current approach generates considerable environmental and social costs and growing levels of e-waste globally. Today, the production of electronic devices generates 180 million tons CO_2 annually.[1] According to the Global E-Waste monitor, a record 62 million tons (Mt) of e-waste was produced in 2022, an increase of 82% from 2010. Only 22% of this e-waste is documented as collected.[2] From an economic perspective, the same report estimates an annual loss of 37 billion USD due to the economic monetary impact of e-waste management; recovery of the metals contained in the e-waste generated in 2022 would deliver the industry 91 billion USD instead.

Adopting circular business models can help the industry reduce some of these negative externalities while retaining and creating value for users and stakeholders. Implementing a circular strategy can lead to an estimated industry average of 12% in cost savings and 10% CO_2 emission savings.[3] Avoiding GHG emissions can deliver over 23 billion USD of monetized value for the industry.[4]

From a regulatory, consumer and innovation perspective, things are coming together in the transition to circularity. Stronger regulatory pressures in support of the circular economy are advancing in many countries (such as extended producer responsibility schemes and EU CSRD), while consumers demand for sustainable products and service models soars and new, innovative technological solutions emerge. Consistent measurement of circular business models' performance and progress has become foundational to communicating transparently to regulators, consumers, investors, and stakeholders, ultimately driving circularity innovation and transformation for the sector.

A circular electronics value chain is a system that works collaboratively to reduce waste and maximize the value of resources where materials and products retain the highest value.[5] All stakeholders across the value chain have a role to play to support the system transformation needed to transition from a predominantly linear to a circular electronics value chain. To address this need, in 2021, WBCSD and five other leading organizations launched the Circular Electronics Partnership (CEP) with the objective to facilitate effective collaboration throughout the entire electronics value chain. Working with private sector members, they developed an ambitious Circular Electronics Roadmap that calls for the industry to **design for circularity, drive demand for circular products and services, scale responsible business models, increase official collection rates, aggregate for reuse and recycling, and scale secondary material markets.**[6]

We have developed this guidance in collaboration with CEP partners and our member companies to support the quantification and communication of the value of circular products and services, a key objective of CEP's roadmap. The guide does this by creating alignment and convergence on circularity progress measurement spanning the full value chain through the adoption of a robust set of metrics for circularity based on WBCSD's widely adopted Circular Transition Indicators (CTI).

The guidance introduces the CTI methodology from a sector perspective and addresses each value chain activity separately providing standardized definitions, principles, recommended metrics, and strategies to support industry wide comparisons and generate comparable and decision-useful data to keep materials and products in use at their highest value for all players in the value chain.

We invite all stakeholders in the electronics value chain to adopt CTI as their preferred framework for circular performance. By speaking a common language and adopting a unified way to measure success, we can successfully transition to a

Introduction

01.

01. Introduction

Transparency and alignment are critical to establishing a common language for circularity across industries and value chains. For this reason, 50+ global companies have come together through WBCSD to develop the Circular Transition Indicators (CTI).

CTI has proven 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.[7] Central to CTI is a self-assessment that determines a company's circular performance to help it find opportunities and become more circular in the future. CTI 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 material flows.

Built for business by business, CTI provides companies with a common language for internal decision-making and communication with key stakeholders. It aligns with voluntary and mandatory regulatory standards, such as the Global Reporting Initiative (GRI 301 and 306), International Organization for Standardization (ISO) 59020 Circular Economy Standard and Corporate Sustainability Reporting Directive (CSRD), which focus on the circularity of resource use and its impact on sustainability. Since its launch, companies from all sectors, geographies and sizes have adopted CTI. The framework is currently in its fourth version and the methodology in continuous development to support companies' needs in a constantly evolving regulatory landscape.

This guidance promotes circularity measurement in the electronics value chain and provides a standardized approach based on CTI for electronic devices. **The guidance supports all players in the electronics value chain and focuses on creating alignment and convergence of circular strategies across the full value chain, from raw material extraction to manufacturing, distribution and retail and preparation for reuse and recycling.**

Circular economy in the electronics sector

The modern world leans heavily on electronic products. Smartphones keep people connected with friends and family, laptops facilitate work tasks and washing machines provide home assistance. Companies integrate digital infrastructure (e.g., servers) with emerging technologies like artificial intelligence or blockchain, fostering innovation in products, services and business models. Yet, as crucial as electronic products are to society, so too is the imperative to make this rapidly expanding industry more sustainable.

The electronics sector produces significant greenhouse gas emissions (GHG), contributing to the accelerating pace of climate change. The manufacturing process of new electronic products, especially information and communications technology (ICT) devices, is a key source of these GHG emissions. Between 2014 and 2020, GHG emissions from selected e-waste generated by ICT devices increased by 53%. Without specific interventions, estimates show these emissions will increase further by 2030.[8] **The industry also generates massive amounts of electronic waste, much of which is classified as hazardous and poses health risks, particularly in communities in developing nations where e-waste is often improperly disposed of.**

Today, the production of electronic devices generates 180 million tons CO_2 annually.[9] **The Global E-waste Monitor found that, the world has generated a record of 62 billion kg of e-waste in 2022, an average of 7.8 kg per capita; only 22.3% of which documented as properly collected and recycled leaving US$ 62 billion worth of recoverable natural resources unaccounted for and increasing pollution risks to communities worldwide.**[10]

The electronics industry is also grappling with economic challenges, including shortages of essential materials like lithium, which is vital for battery production. The demand for finite materials, including critical raw materials used in electronics, is resulting in highly volatile markets and adding uncertainty to the industry.

Adopting a circular economy approach offers a means to reduce carbon emissions, help prevent e-waste loss to landfills, mitigate supply chain shortages and reverse biodiversity loss. In terms of financial opportunities, the world's electronic waste holds material value amounting to USD $60 billion in 2019 through the implementation of innovative circular business models and optimization of the product life cycles throughout the value chain.11

To support this much-needed transition, six global organizations dedicated to driving business solutions for a more sustainable world established the Circular Electronics Partnership (CEP) in 2021. CEP unites leading companies across the electronics value chain behind a shared vision and roadmap that help drive a coordinated transition to a circular electronics industry.

In this context, the adoption of a standardized measurement protocol for circularity plays a critical role in uniting the industry on common sustainability objectives. Electronics sector businesses need a methodology that can credibly quantify and steer the impact of circular strategies on net-zero, nature-positive and equity goals. In response to this need, the World Business Council for Sustainable Development (WBCSD) developed the Circular Transition Indicators (CTI) as a flexible business methodology to measure circularity.

The electronics sector guidance, developed in a collaborative effort with CEP and WBCSD members and partners, aims to create a shared understanding and vision in the industry. The objective is to steer the industry to evaluate, adjust and enhance practices to foster a financially sustainable circular electronics industry. By adapting these indicators to the unique contexts of the electronics sector and getting the sector to employ them, the guidance creates a clear path for the industry's transition to a circular economy, supporting individual companies in measuring their performance in an industry-aligned way and steering all players in the value chain towards a future that is both sustainable and inclusive for all.

Circular electronic products

For the purpose of this guidance, we have adopted the following definitions:

Electronic products are all types of electronic and electrical equipment as defined by the EU's Waste from Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU. This includes devices and equipment from six product categories: temperature exchange equipment, screens and monitors, lamps, large equipment, small equipment and small information technology (IT) devices.[12]

Circular economy, as defined by the Ellen MacArthur Foundation, is an system that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value while eliminating the input of raw materials in the value chain and reducing waste streams.[13] This definition focuses on the outcome-oriented notion of the circular economy as circular design principles are often associated with the definition of circular products.

Circular products are defined by CEP's Circular Electronics System Map as follows:

1. The product is made from verified circular resources;
2. The product is designed for use-phase optimization and material recovery;
3. The product's use phase is optimized and materials are recovered at end of life.[14]

Circular electronics value chain

A circular electronics value chain is a system that works collaboratively to reduce waste and maximize the value of resources where materials and products remain in the value chain,[15] retaining the highest value from available materials. It requires close engagement with partners on sourcing circular materials, designing products and business models for longevity, repairability multiple use cycles and recyclability, as well as implementing strategies to reuse devices and recover materials from end-of-life products. By adopting circular principles, the electronics industry can reduce its environmental impact, preserve resources and create economic opportunities.

At present, the electronics sector operates within a predominantly linear economy fueled by traditional business models. A circular electronics value chain includes all steps required to deliver an electronics device, from raw material extraction to manufacturing, retail and distribution. It also includes activities required to slow, narrow and close loops through activities that extend the lifetime of the products, such as reuse, repair, refurbishment, remanufacturing and material recovery at end-of-life through recycling.16 These are needed to deliver a circular electronic device.

Figure 1 shows this alongside the conventional linear business model.

Figure 1 presents the electronics value chain in chronological order, where the recovery of products, components and materials can happen throughout the life cycle of the electronic device under scope. **CTI measures resource use and its impact on climate and nature at the corporate, facility/asset and product level. Companies can identify which activities may be most relevant to assess first and refer to recommendations included in this guidance according to the activity or sub-activity.** The steps outlined in the table below explain how companies can use CTI to assess and measure progress. For the purpose of this guidance, reuse, repair, refurbishment, remanufacturing and recycling activities are based on the lifetime extending activities outlined in International Organization for Standardization (ISO) 14001.17

The activities and sub-activities outlined below are necessary to deliver a circular electronic device. We have structured this document along these activities. **Companies will refer to the sections most relevant to their position in the value chain for guidance on how to perform a CTI assessment.**

Figure 1: Circular electronics alongside the traditional value chain

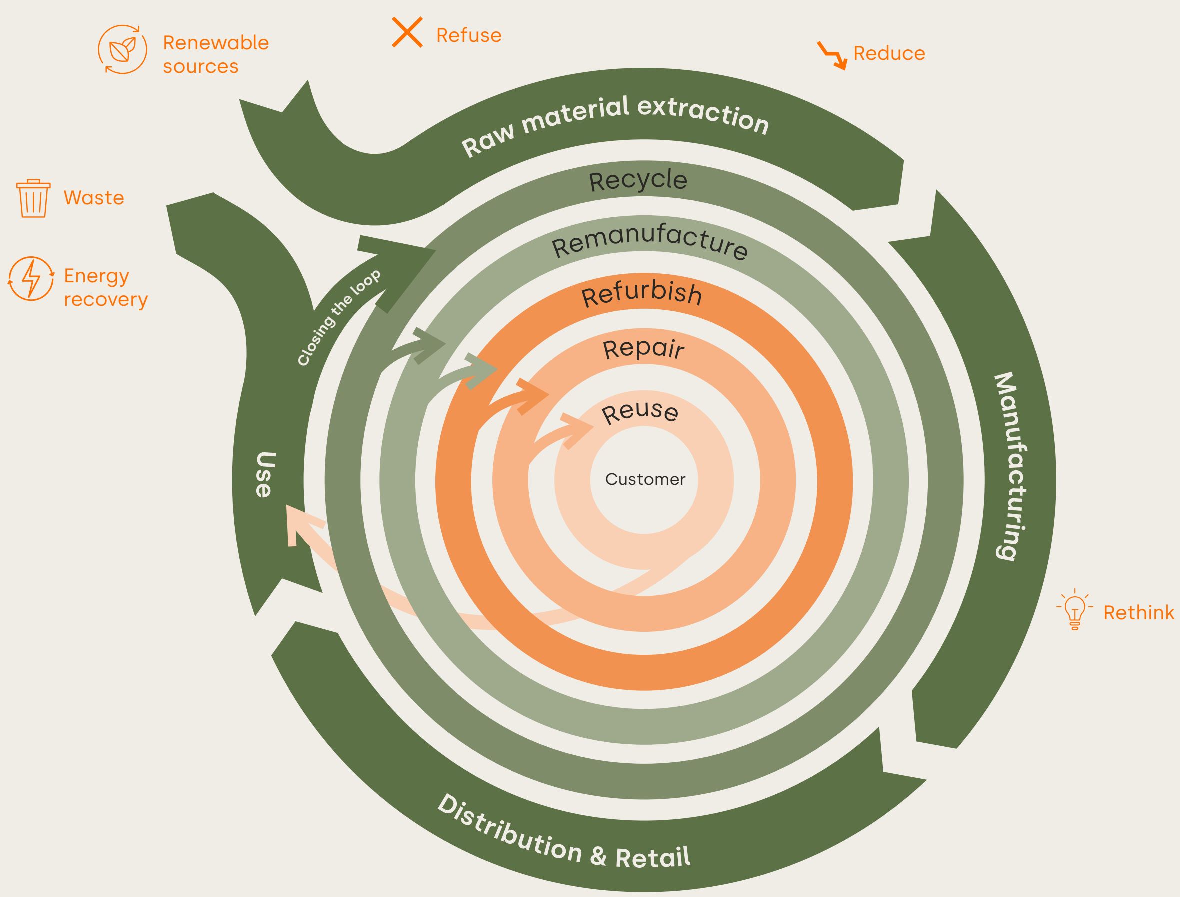


Table 1: How companies can use CTI to assess and measure progress

	Description	Sub-activities
Raw material extraction	The initial stage involves the extraction and production of raw materials for producing an electronic product.	→ Extraction of raw materials like metals, silicon, plastics etc. → Refining processing of raw materials → Quality control and assurance processes → Preparation of materials for transport to manufacturers → Outflow of the materials → Packaging materials for transport to component manufacturing
Manufacturing	In this step, the raw materials are turned into various components and products. A distinction is made for the different steps on the type of manufacturing company e.g., component manufacturing company, contracting manufacturing company, and OEM assembly and manufacturing company.	**Component manufacturing company:** → Inflow of materials from raw material extraction or other sources such as recycled materials → Design of components → Sourcing and procurement → Machining and fabrication → Assembly and integration → Maintenance and servicing of production → Quality inspection → Outflow of the component → Packaging components for transport to OEMs or contracting manufacturers
		Contracted manufacturing company and/or OEM assembly and manufacturing company: → Designing the final product → Sourcing and procurement → (Potentially) producing components → Assembly of variety of components into a final product → Installation of operating systems and software → Conducting quality checks and regulatory compliance tests → Packaging products for transportation (distribution or retail) → Handling logistics and distributing finished products → Providing after sales service such as warranty and repairs
		Brands Brands may not have physical materials flowing through company boundaries as they often contract manufacturing to partners. Electronic products still carry their brand logo and name. Brands can best refer to the manufacturing guidance to conduct their CTI assessments, which provides suitable guidance for selecting indicators and collecting data.

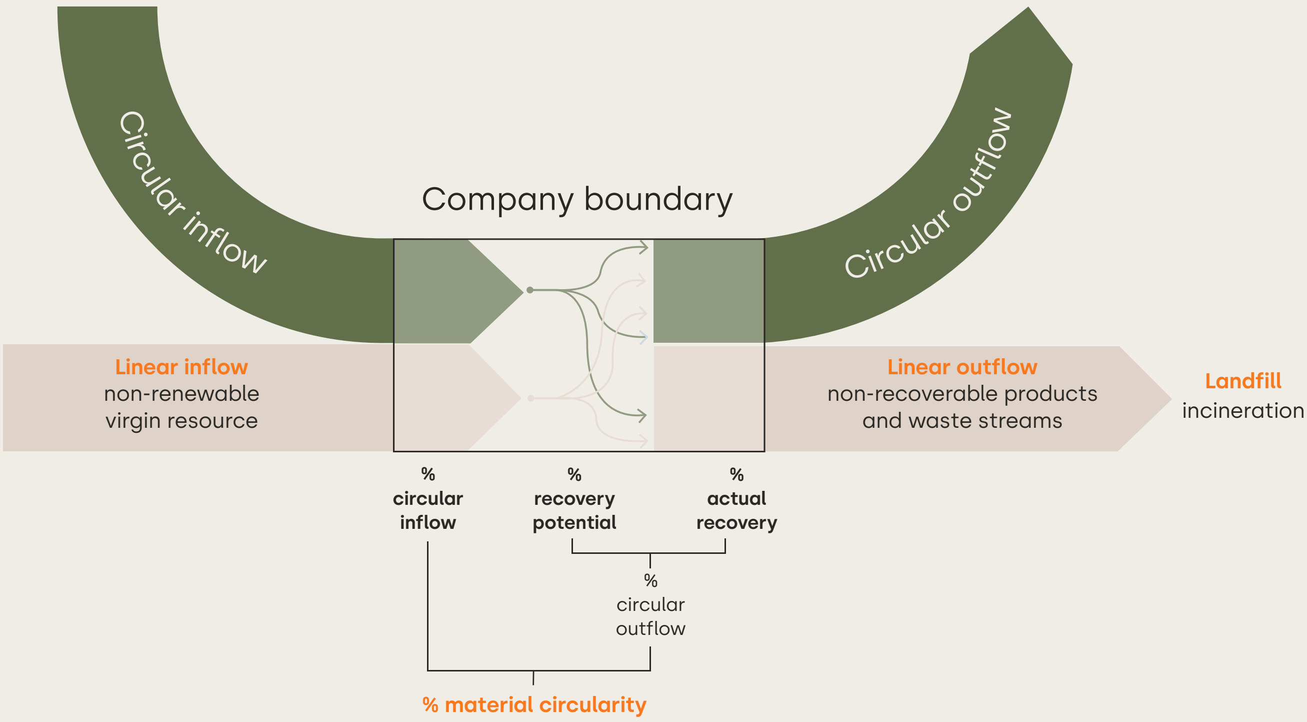
	Description	Sub-activities
Distribution and retail	Once the products are manufactured and assembled, they are packaged and distributed to various wholesalers, retailers, or directly to customers.	→ Inflow of products from the OEM or contracting manufacturing company → Packaging the final product → Organizing the logistic services for product delivery → Managing inventory → Facilitating sales through different channels → Outflow of products to the user → Providing after sales service such as warranty and repairs
Use	This is the stage where the product is with the customer, being used for its intended purpose. This stage also includes software updates or accessories that may extend or enhance the usability of the product.	→ Inflow of the product by distribution or retail company → Consumers use the product for its intended purpose → Regular updates of software if required → Purchase of add-ons or accessories for enhancing product functionality
Preparation for reuse	Preparation for reuse is a stage in the electronics value chain where products that have reached the end of their current useful life — either because they are broken, outdated, or no longer needed — are processed to be used again to extend their lifetime. This stage involves implementing R-strategies such as reuse, repair, refurbishment, and remanufacturing to extend the lifespan of the device. Lifetime extension measures can occur at different stages in the electronics value chain. For example, after an end-user has used an electronic device that is now broken, it can be repaired to extend its lifespan. Similarly, a manufacturer can refurbish spare parts or components to be used elsewhere with a different functionality, further extending the lifespan of the material or electronic component or device.	→ Collection of end-of-life electronic devices from consumers, partners, or businesses → Sorting and categorizing electronic devices based on their condition and potential for reuse → Software based data sanitisation → Cleaning and repairing electronic devices to prepare them for reuse → Packaging and labelling electronic devices for distribution to wholesalers, retailers, or customers → Organizing logistics for the delivery of refurbished electronic devices to their destination → Managing inventory of refurbished electronic devices and tracking their sales and distribution → Providing after-sales service such as warranty and repairs for refurbished electronic devices → Responsible recycling of electronic devices after any components which may be reused in different devices have been removed
Recycling	Recycling is a stage in the electronics value chain where products, components or materials are no longer viable for reuse, refurbishment or remanufacturing. Companies use methods such as mechanical or chemical processes to recycle them.[18]	→ Collection of end-of-life electronic devices from consumers, businesses, or waste handlers → Sorting and categorizing electronic devices based on their material composition and potential for recycling → Dismantling electronic devices to separate different materials and components → Shredding or crushing electronic devices to reduce them to smaller pieces → Sorting, refining, and purifying recovered materials to remove impurities and prepare them for reuse iew products → Managing waste streams and by-products generated during the recycling process

The methodology behind the Circular Transition Indicators

CTI is based on material flows through a company boundary. 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 sources?
- **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?

Figure 2: Illustration of material flows



The Indicators

Central to CTI is a self-assessment that determines a company's circular performance to help companies find opportunities and become more circular in the future. 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 manages its material flows.

WBCSD published a first version of CTI in 2020 and developed the framework based on four modules, each addressing different, but complementary, aspects of circularity:

1. **Close the Loop –** This module calculates the company's effectiveness in closing the loop on its material flows.
2. **Optimize the Loop** – This module provides insights on material criticality, resource-use efficiency and higher value recovery strategies.
3. **Value the Loop –** This module illustrates the added business value of the company's circular material flows.
4. **Impact of the Loop –** This module measures the difference in impact between the company's current circular performance versus 100% circularity.

Figure 3: The four modules of the Circular Transition Indicators v4.0

1 *Close the Loop*	2 *Optimize the Loop*	3 *Value the Loop*	4 *Impact of the Loop*
→ % material circularity → % water circularity → renewable energy	→ % critical material → % recovery type → actual lifetime → onsite water circulation	→ circular material productivity → CTI revenue	→ GHG impact → nature impact

(Refer to CTI v4.0 for more detailed information on how to calculate all indicators outlined above).

Understanding CTI: Scope and limitations for the electronics sector

Through this guidance, businesses and key stakeholders in the electronics industry value chain have joined forces to develop a standardized sector approach to measuring circular performance. It equips value chain stakeholders in the electronics industry to use the robust set of circularity metrics for business including in CTI and helps companies mitigate risks, demonstrate the business case for the value chain and report their progress on circularity. **With its transparent and quantitative approach, global adoption and alignment with both voluntary and mandatory reporting standards, CTI presents the ideal set of indicators for adoption by industry.** This guidance aims to facilitate the use of CTI to promote accountability, create value and operationalize circularity roadmaps.

CTI provides a methodology that helps organizations quantify and improve their circularity by providing a common baseline for quantifying circular performance, setting targets and engaging with other parties in the circular value chain. While CTI offers valuable insights and indicators for assessing circularity in business practices, it is best to use it alongside other methodologies to ensure a comprehensive evaluation of circular performance, particularly when considering regulatory requirements, broader ecosystem impacts and financial aspects.

Navigating the regulatory landscape

Built for business by business, CTI provides companies with a common language for internal decision-making and communication with key stakeholders. It aligns with voluntary and mandatory regulatory standards, such as the Corporate Sustainability Directive (CSRD) and ISO 59020, on the circularity of resource use and material extraction and the impact on sustainability reporting. Since its launch, companies from all sectors and geographies and of all sizes have adopted CTI.

While CTI does not replace other relevant assessments, like value chain analysis or life-cycle analysis (LCA), it does provide a valuable starting point for companies looking to transition to a more circular economy. CTI provides a valuable methodology to measure circular performance. In preparing to report on mandatory voluntary frameworks, companies should note that they should transparently communicate any assumptions and base their results on high-quality data informed by complementary environmental impact assessments such as LCAs (see p.21 for an overview of CTI's complementarity with sustainability frameworks).

CTI aligns with reporting standards for resource use and circular economy. For example, companies can use it to collect data and insights to inform reporting on requirements outlined in the European Union's Corporate Sustainability Reporting Directive (CSRD) – European Sustainability Reporting Standards (ESRS) E5 on Resource Use and Circular Economy.[19] A whitepaper **Preparing the road to circular economy reporting** developed by KPMG in collaboration with WBCSD explores this alignment further.

How to read this guidance

The document's structure consists of two main sections:

Part 1 – General CTI explanation
This part provides an overview of CTI and how to perform an assessment across its seven steps.

Part 2 – Value chain-specific CTI application
This section provides guidance on how to perform CTI's first three steps (Scoping, Selecting and Calculating) for the different activities identified in the circular electronics value chain: Raw materials extraction, Manufacturing, Distribution and retail, Use, Preparation for Reuse and Recycling.

Users should refer to the company's predominant business activity for guidance on how to perform steps 1–3 of the CTI assessment. For instance, if the company manufactures electronic devices, it shall refer to the Manufacturing section. Similarly, if the company's primary business activity is retailing electronic devices, refer to the Distribution and retail chapter.

Although a company may be involved in multiple activities outlined in the value chain, the guidance is most effective when referring to the main business activities as, for example the manufacturing chapter will also address sub-activities such as retail or repair. Brands may not have physical materials flowing through their company boundaries as they often contract manufacturing to partners. Electronic products still carry their brand logo and name. Brands can best refer to the manufacturing guidance to conduct their CTI assessments, which provides suitable guidance for selecting indicators and collecting data.

Part 1

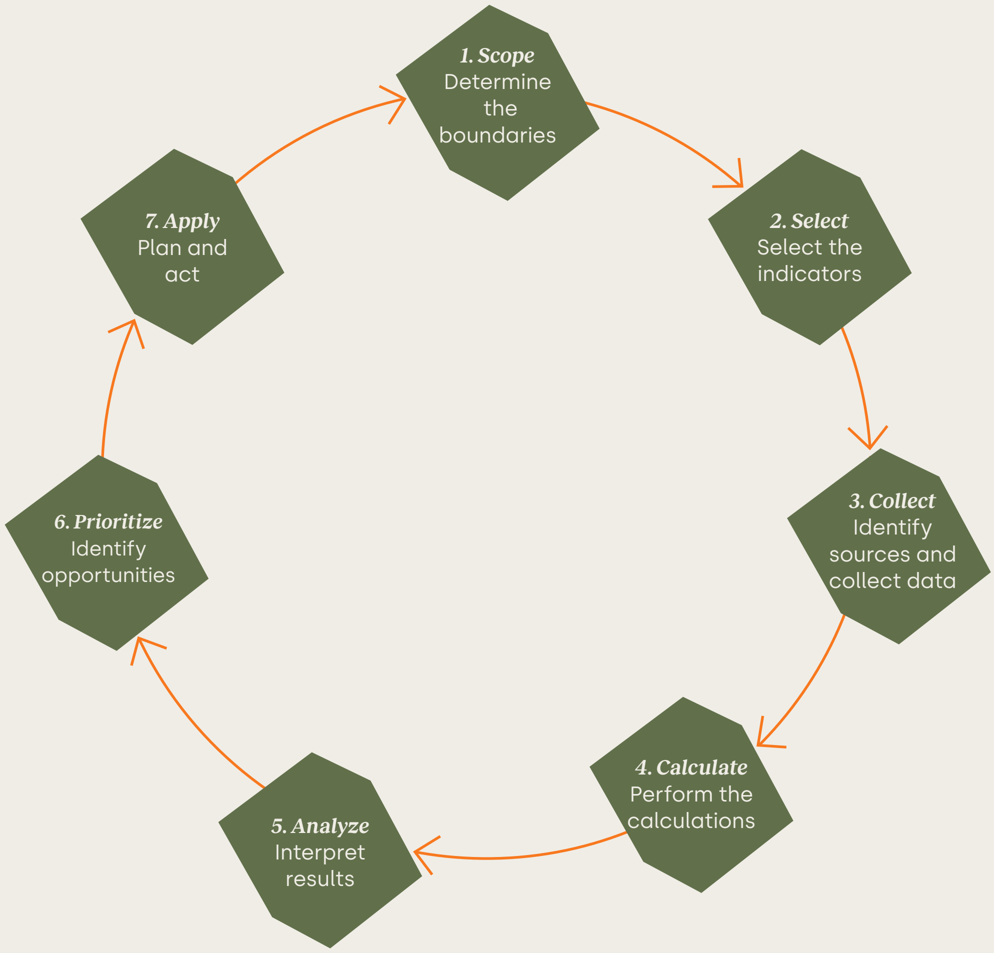
→ *General CTI explanation*

02.

02. Part 1
General CTI explanation

CTI provides seven cyclical steps to support companies in quantifying their circular performance. Building a baseline, setting targets and periodically monitoring progress enables operationalization of circular approaches across the company. A clear methodology with specific steps that companies repeat enables decision-makers to understand the impact of circular approaches over performance and business models. Once a company has conducted a circular assessment, decision-makers should reflect on the outcome of the assessment and define next steps to continuously monitor progress, improve decision-making and prepare for the next assessment.

Figure 4: The seven steps in the CTI framework



Step 1 – Scope

In step 1, the company determines which materials, components and products are in scope for the CTI assessment. CTI is flexible and applicable to the materials flowing across company boundaries at different levels (e.g., corporate, asset, facility, product) based on the insights the company wants to derive from the assessment. For example, a company in the electronics value chain may choose to include the material streams flowing through one of its contracted manufactures or decide to only focus on the material streams directly flowing through its own company boundaries. A company offering a service model may adjust the company boundaries to reflect the material streams flowing in and outside of the company boundaries when clients return products.

The questions below can support companies in determining the scope.

1. ***Why is circularity important for the company?***

   Transitioning to a circular electronics value chain has the potential to fundamentally change the way its stakeholders design, manage resources and implement business models. Overall, circularity is important for companies as it can help them to achieve sustainable growth, reduce environmental impacts and enhance reputation as responsible and forward-thinking businesses. Table 2 outlines a few examples of opportunities that transitioning to circularity can deliver to players in the electronics value chain.

Table 2: Why is circularity important for the company?

Resource efficiency: A circular approach for electronic devices can help companies to use resources more efficiently, reduce waste, and minimize the use of virgin materials. For electronics companies, adopting circular practices involves designing products with modular components for easy repair and upgrade, which can minimize electronic waste, encouraging a more efficient use of resources.	**Supply chain resilience:** In the electronics industry, adopting circular practices is crucial for enhancing supply chain resilience. By incorporating recycled, reuse or renewable materials into product manufacturing and designing devices with reuse in mind, electronics companies can diversify their material sources and reduce reliance on virgin inputs. This not only strengthens the supply chain against disruptions to conventional material supply channels but also serves as a buffer, reducing vulnerability to fluctuations in commodity prices and potential supply chain interruptions.	**New business models and innovation:** Circular economy principles encourage innovation by promoting the development of durable, repairable, and recyclable products and services. Electronic devices designed with circular principles, such as easy disassembly and recycling-friendly materials, showcase innovation and give companies a competitive edge in the electronics market. Innovation led by circular principles can drive new business models and growth opportunities, enhancing market competitiveness and create new revenue streams.
Cost savings: By reducing waste and optimizing resource use, companies can save costs associated with raw materials, production, and waste disposal. Reusing valuable materials from returned or obsolete devices for example can lower production costs and decrease the demand for new raw materials.	**Environmental impact:** A circular economy approach can help companies reduce their environmental impact by minimizing waste and emissions and promoting the use of renewable (energy) sources. By focusing on product life extension, responsible sourcing, and waste reduction, circular electronics companies contribute to broader environmental objectives.	**Reputation:** Adopting a circular economy approach can enhance a company's reputation as a responsible and sustainable business. Companies that prioritize e-waste management, lifecycle extension, (responsible) recycling initiatives, and sustainable sourcing enhance their brand reputation, appealing to environmentally conscious consumers, investors, and other stakeholders.
Risk mitigation: Electronics manufacturers face supply chain risks related to the availability of rare minerals and metals. Embracing circularity by responsibly sourcing materials and establishing take-back programs mitigates these risks, ensuring a stable and ethical supply chain. Linear models that involve the extraction, production, use, and disposal of products can expose a company to supply chain vulnerabilities, resource scarcity, and regulatory risks. Circular approaches can promote resilience and adaptability, mitigating these risks.		

2. *Which insights do we want to develop?*

CTI helps companies in the electronics value chain evaluate their performance in transitioning to a circular economy. Companies can gain insights into various aspects of its operations by answering to critical questions such as:

- → How to transition from a linear to a circular model in our business operations?
- → How to set a baseline for circular performance and how to improve over time?
- → How circular is our new product?
- → How do we track performance of circular decisions made?
- → How well have we designed our products for durability, repairability and recyclability?
- → How efficiently are we using materials and what efforts are in place to minimize waste in our processes?
- → To what degree do our up- and downstream suppliers align with circular economy principles?
- → How can we collaborate with up- and downstream suppliers to improve the overall circularity of the value chain?
- → How can we enable customers to be more circular?
- → How can we contribute to higher circularity rates for electronics?
- → How does circularity contribute to better overall business performance?
- → How can we ensure compliance with relevant regulations related to electronic waste management and circular economy practices, such as the voluntary Global Reporting Initiative (GRI) and mandatory regulations like the Corporate Sustainability Reporting Directive (CSRD)?

3. *Who is the audience of the assessment's outcomes and insights?*

Transitioning to a circular economy requires collaborative efforts within a single company as well as throughout the value chain. This means that the audience for a CTI assessment outcomes and insights can vary and may include a range of stakeholders having an interest or impact in the company's contribution in a transition towards a circular economy.

Table 3: Audience of the assessment's outcomes and insights

Internal stakeholders	External stakeholders
Company leadership and management: CTI outcomes can help executives, board members and senior management understand the current state of circularity and guide decisions on future strategic direction and investments. **Employees:** Leaders can share CTI outcomes internally to engage and motivate employees, fostering a sense of pride and purpose in contributing to the company's circular objectives.	**Customers:** Consumers are increasingly concerned about the environmental impact of the products they purchase. Companies can communicate CTI outcomes to showcase efforts to adopt circular practices, influencing brand perception and potentially attracting environmentally conscious consumers. **Investors and shareholders:** Investors and shareholders are interested in the company's long-term sustainability and resilience. CTI outcomes provide insights into the company's commitment to circular practices, which can influence investment decisions and shareholder confidence. **Value chain partners:** Sharing CTI outcomes with value chain partners can encourage collaboration and alignment on circular principles, as the company's circular initiatives impact suppliers and other partners in the value chain. **Regulatory bodies and compliance auditors:** Government agencies and regulatory bodies may review CTI outcomes to ensure compliance with relevant regulations. Compliance auditors may also use the information to assess adherence to industry standards and guidelines. **NGOs and advocacy groups:** NGOs and environmental advocacy groups may be interested in CTI outcomes to promote sustainable business practices. Positive outcomes can lead to partnerships or endorsements from these organizations.

4. *What business unit, product group or specific materials should we focus on to start with? Where could impact drive optimal value for all stakeholders?*

CTI offers a varied set of metrics and a flexible approach. It allows the aggregation of results that serve diverse objectives. This supports and enhances the company's strategies and processes, guiding them to become more circular, and improves product performance – giving the company a competitive advantage.

Companies can conduct CTI assessments at several levels. Table 4 shows a few examples.

CTI users should consider several factors when determining the level and scope of their assessments: strategic importance or assessment feasibility including data availability, willingness to participate and the existing infrastructure for implementing circular practices.

Evaluating the feasibility to assess a particular material, product group or business unit in terms of data availability and quality ensures that the evaluation is based on comprehensive and accurate information. All stakeholders within the chosen scope should actively participate in the CTI assessment to increase the likelihood of successful implementation

Companies embarking on their circular journey with limited experience in measuring circular performance should start with small-scale assessments on a material, component or product level. A small-scale approach provides an opportunity for the company to learn and gain experience in measuring circular performance. It allows teams to familiarize themselves with relevant indicators, data needs, data collection methods and analysis techniques before scaling up to broader scopes. Initiating an assessment at the material, component or product level provides a solid foundation for a comprehensive evaluation. By analyzing individual parts of the organization, it is possible to achieve a broader scale assessment of the business unit or company. The sum of these individual assessments often represent the broader scale assessment at the business unit or company level.

Companies that already have experience with measuring circular performance may transition to larger-scale assessments at the business unit or company level. **Assessing circular performance at a larger scale provides a more holistic view of the company's overall performance and impact on circularity**. It allows for a comprehensive evaluation of multiple products, processes and operations within the organization. **The experience gained in the detailed assessment of a product supports the company in understanding the difficulties of the assessment. A broader assessment helps identify systemic opportunities for circular improvements.** Companies can uncover interconnected processes and areas where they can integrate circular practices more effectively.

Table 4: Levels at which companies can conduct assessments

Material	Component	Product	Business unit	Company
→ Metals such as lithium, cobalt, nickel, copper, aluminum and gold → Plastics → Glass → Silicon	→ Semiconductors → Circuit boards → Cables and wires → Other product parts, such as screens, keyboards, mice	→ Batteries → Laptops → Tablets → Phones → Routers → Cameras → Smart home devices → Chargers → Printers → Other consumer electronics or IT equipment	→ B2B → B2C → Technology → Manufacturing and production → After-sales services and repair → Take back operations → Closing the loop: preparation for reuse → Single subsidiary → Single business unit producing one product category	→ Aggregated company level covering all business units → Aggregated group level covering all subsidiaries

5. *How does the CTI assessment interact with other analyses in the company?*

We've built CTI to interact with other analyses within an organization in a synergistic manner, contributing to a comprehensive understanding of the company's sustainability and circular economy efforts.

Table 5: How does the CTI assessment interact with other analyses?

Sustainability reports: CTI contributes data and insights that enhance the quantitative aspects of a sustainability report, offering a detailed perspective of a company's circular performance and initiatives.	**Life-cycle assessment (LCA):** The CTI assessment while encompassing a broader scope, aligns closely with LCA by providing additional insights into recovery potential, material uses and end-of-life considerations.	**Material flow analysis:** The CTI assessment complements a material flow analysis by providing a qualitative and quantitative understanding of how the management, reuse and recycling of materials throughout the organization's processess.
Environmental impact assessments (EIA): CTI assessments can complement EIAs on circular practices that directly impact environmental performance with the Impact of the Loop indicator on GHG emissions or Nature Impact indicator.	**Supply chain analysis:** CTI aligns with a broader supply chain analysis by providing detailed information on circular practices, supplier collaboration and the integration of sustainable sourcing strategies.	**Compliance reviews for reporting such as CSRD materiality and impact, risk and opportunity (IRO) assessments:** CTI assessments provide insights into the company's adherence to circular economy principles and regulatory requirements.

6. What level of the business do we assess?

Each level of assessment contributes to a multi-faceted understanding of the company's circular performance, from the specific composition and recovery of materials to the overarching circular economy strategy at the company level. By addressing circularity at different levels, companies can tailor their efforts to specific challenges and opportunities within each domain while contributing to a comprehensive and cohesive circular economy strategy.

Integration across levels

Objectives

- → Ensure alignment and consistency in circularity objectives across different assessment levels
- → Identify synergies and opportunities for cross-functional collaboration
- → Streamline reporting and certification processes to provide a cohesive overview of circular performance

Considerations

- → Establish clear communication channels and mechanisms for sharing insights and best practices across different levels
- → Develop a centralized system for data collection and reporting that facilitates integration across the material, product, business unit and company levels

Table 6: Objectives and considerations in an assessment

	Material	Component/ Product	Business unit	Company
Objectives	Evaluate the circularity of individual materials such as metals, plastics, glass, silicon and steel. Identify opportunities to improve material efficiency and minimize waste by implementing circular practices in design, sourcing and waste management, with a focus on reusing materials. Identify opportunities to transition to more circular materials to increase supply chain resilience and reduce cost.	Evaluate the circularity of one component or product or the entire category (e.g. batteries, laptops, phones, semiconductors). Identify opportunities for improving the circularity of products and their components. Benchmark the products circularity performance against industry standards or competitors. Collaboration with up- and downstream suppliers to improve the value chain circularity. Comply with product-related reporting or certification requirements.	Evaluate and compare the circularity across various business units to gain valuable insights into their material use patterns. Identify opportunities to implement circular practices that increase business performance and profitability. Reduce the environmental impact of operations and processes associated with a particular business unit.	Evaluate the circularity at company level. Evaluation of overall circularity goals, strategies and progress at the company level. Define a circular roadmap for the entire organization. Identify opportunities to develop circular economy business models. Identify partners and collaborations to drive circularity initiatives throughout the value chain. Comply with reporting or certification requirements at the company level.
Considerations	Collaboration with suppliers and recycling companies is crucial to optimizing the circularity of individual materials.	Consider the entire product or component life cycle, including manufacturing, use and end-of-life stages, to identify areas for improvement.	Tailor assessments to the specific operations and products/services of each business unit. Integrate with existing sustainability and corporate social responsibility initiatives within the business unit.	Comprehensive assessments at the company level require coordination and collaboration across all business units. The company-level assessment informs strategic decision-making and shapes the overall circular economy strategy.

CTI use case — HP

The plastic material used in HP ink cartridges contains on average 51.6% of post-consumer recycled plastic (HP sustainable impact report 2022). HP has implemented a closed loop system to recycle empty ink cartridges through a service that automatically replaces cartridges and helps users send empty ones back to HP. The closed loop operations give HP insights into primary data on the percentage of ink cartridges recovered, helping to reduce waste and increase recycling rates. HP gathers data for materials that flow into downstream recycling vendors, such as precious metal smelters and the closed loop plastic that goes to HP plastic compounders - on the most sold cartridge family closed loop operations provide a minimum of 5% of the recycled plastic.

7. *What is the timeframe?*

When working with CTI, the company may consider different timeframes depending on the objective of the assessment (determined based on the previous questions). The timeframe could range from several years of material consumption, one year of production, a batch of production or simply the time frame of the production of one product. It's important to consider different timeframes, potentially applicable to various levels of assessment. The overview in Table 7 is extensive but not exhaustive. The company has the possibility to assess the production of one product based on materials used in production and multiply with the number of products produced during the chosen timeframe.

Table 7: Objectives and considerations in an assessment

Material	Component/ Product	Business unit	Company
Material use for time period of 1 year; one production cycle (of one product)	1 year (fiscal/reporting time frame); one production cycle; two products of the same type subject to circular economy related changes.	1 year (fiscal/reporting time frame); one production cycle	1 year (fiscal/reporting time frame); one production cycle

8. *What do we include and exclude?*

When conducting a CTI assessment, it's crucial to include and exclude specific elements to ensure a comprehensive and focused evaluation.

The following chapters provide detailed descriptions of which indicators and data to include or exclude for specific activities.

There are no right or wrong reasons to include or exclude materials streams. It is important to carefully consider and document what the company is excluding and why. The company must always include this during the analysis and synthesis of the conclusions, as well as in any communication to the final audience of the results.

Table 8: What do we include and exclude?

	Material	Component/ Product	Business unit	Company
Include	Materials contained in or used to produce the product or product group that should be assessed Assessment of the sourcing practices for materials, considering recycled content and sustainable sourcing Assessment of the recovery and reuse practices for materials, considering reuse and recycling rates	Materials and components contained in or used to produce the product or product group that should be assessed Design considerations, manufacturing process considerations, product lifespan and end-of-life management	Products and their components and materials that are related to the business unit that should be assessed Waste or residues that result from production processes of the business unit Evaluation of manufacturing and production processes covered by the business unit	All products produced or sold by the company
Exclude	Materials not included in the product under assessment or are not directly related to the production process Aspects unrelated to the specific materials used in electronic devices, such as non-material-specific energy consumption	Materials or components not included in the product under assessment or not directly related to the production process Materials that make up an insignificant amount of the product and are not considered a rare or critical material (e.g., materials used in quantities below <x% of total weight) Operational aspects not directly related to the specific product life cycle, such as corporate administration processes	Product-specific considerations that are not directly related to the business unit operations Overarching company-wide initiatives that are not directly associated with the specific business unit	Highly granular details that are better addressed at lower assessment levels Specifics related to individual products or materials that are more suited for product or material-level assessments

Step 2 – Select

Once the company has defined objectives of the CTI assessment, it can proceed with the selection of indicators in line with the material topics for the electronics industry. We encourage the selection of specific indicators for the subsequent steps.

For each activity in the value chain, we provide recommendations on the indicators to select for each level of the assessment. This is available in Part 2 below. For each of the activities shown in the value chain and each level of the assessment, we define which indicator is **required, recommended or optional**.

In line with this, "required" refers to indicators needed to perform the calculation of the % material circularity indicator but not necessarily mandatory for other purposes. For assessment focusing on other purposes, organizations within the electronics value chain are at liberty to select indicators they find most relevant.

Step 3 – Collect

After selecting the indicators, the company will proceed **to collect data for the calculations**. The second part of the sector guidance provides detailed explanations on how to best prepare the data collection process for each indicator for each activity in the value chain. This includes information on which specific data points to use and where to find them.

Generic and specific indicators

This sector guidance differentiates between generic and specific indicators. Generic indicators have a similar data collection process across the entire value chain, while specific indicators require a differentiated approach for each value chain activity.

Table 9 shows this distinction for all CTI indicators to emphasize the need for tailored data collection processes for specific indicators based on a company's position in the value chain. **Guidance on data collection for the specific indicators for different activities in the value chain is available in the second part of the sector guidance. Guidance on the data collection for the generic indicators is available in CTI v4.0.**

Table 9: Specific indicators included in the guidance

Indicator	Generic/specific	Link
% circular inflow	Specific	Part 2 – Value chain-specific CTI application for every activity in the value chain
% circular outflow	Specific	Part 2 – Value chain-specific CTI application for every activity in the value chain
% water circularity	Generic	CTI v4.0[20]
% renewable energy	Generic	CTI v4.0
% critical raw material	Specific	Part 2 – Value chain-specific CTI application for every activity in the value chain
Recovery type	Specific	Part 2 – Value chain-specific CTI application for every activity in the value chain
Actual lifetime	Specific	Part 2 – Value chain-specific CTI application for every activity in the value chain
Circular material productivity	Generic	CTI v4.0
CTI revenue	Generic	CTI v4.0
GHG impact	Generic	CTI v4.0
Nature impact	Generic	CTI v4.0

To ensure an efficient data collection process, a company needs to address a set of key topics:

1. Data points required per indicator
2. What data to include and exclude
3. Level of detail of the data
4. Recommendations for data collection

Part 2 provides guidance on how to address these topics per value chain activity:

→ Raw material extraction
→ Manufacturing
→ Distribution and retail
→ Use
→ Preparation for reuse
→ Recycle

Data quality and availability

External value chain data

Companies can find data with external partners and within their own organization. To conduct the assessment, companies usually rely strongly on external data from both up- and downstream value chain partners.

The most reliable and precise approach is to obtain primary data from value chain partners, as they provide first-hand information about the specific material, component or product being assessed. Third-party verification of supplier data, for example getting a certification on the use of recycled materials in production from an independent organization, is encouraged and considered a best practice.

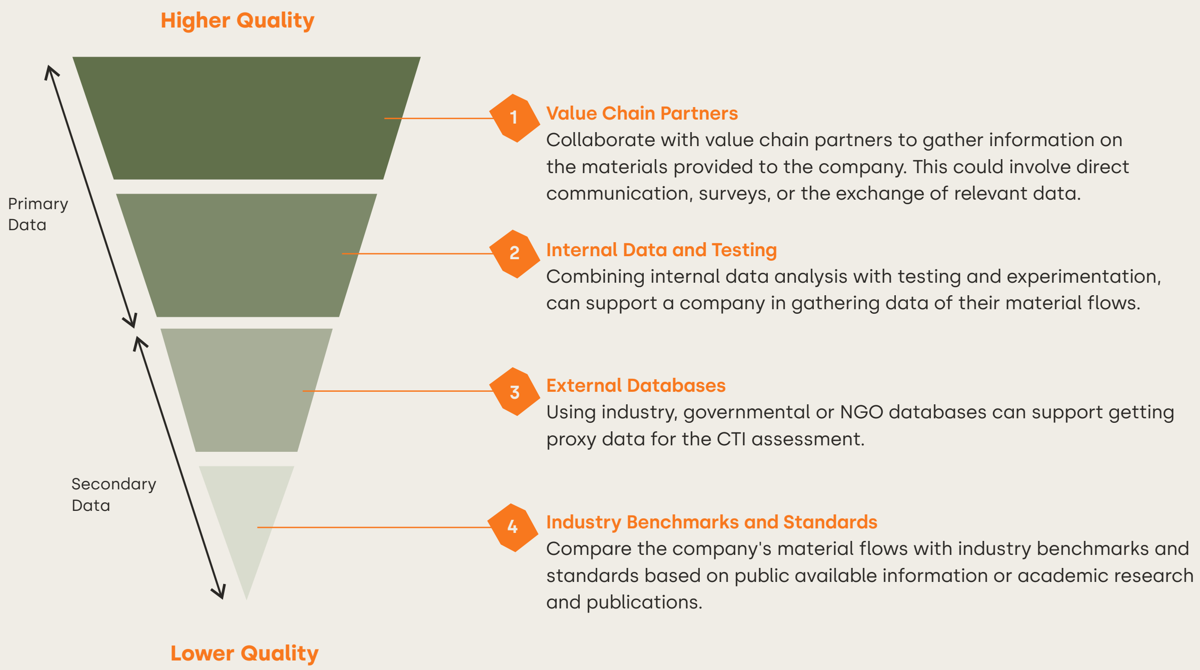
When primary data is unavailable, a company may resort to using proxy or benchmark data, also referred to as secondary data. These can be obtained from publicly available or paid sources such as databases, research or publications. While secondary data can be useful, it is generally less specific to a certain product or region and considered of lower quality and accuracy compared to primary data.

A company should prioritize obtaining primary data and only resort to using indirect data if primary data is unavailable. It is also possible to combine primary and secondary data for the assessment.

Figure 5 shows the level of quality per data source spread across the possible primary data sources and secondary data sources.

Data collection is likely to be the most labor-intensive part. Some data points might be relatively easy to obtain, while others will require collaboration with value chain partners and peers.

Figure 5: **Level of quality per data source**



CTI use case – Philips

Philips is a health technology company. Its purpose is to improve the health and well-being of 2.5 billion people annually by 2030. It has operationalized its purpose by adopting a fully integrated approach to doing business responsibly and sustainably. Its circularity ambition is to help customers "do more with less" by applying its circularity principles "use less, use longer and use again" in five strategic areas, from design to end-of-use management. Philips has committed to delivering on voluntary circularity targets by 2025 as part of its environmental, social and governance (ESG) commitments, which includes generating 25% circular revenues. Circular revenue is an overarching metric that collates practices at Philips related to products, services and solutions that contribute to circularity. It measures the revenue contributions from design to responsible end-of-use management.

Philips reports on materials recycled into raw materials based on different data sources, depending on the product type. It uses data from either a certified recycling network or collected via national recycling schemes for medical equipment (recycling network) or consumer products (national recycling schemes). This supports reporting on recycling and provides inputs for the % circular outflow indicator in CTI.

- → **Primary data collection for % actual recovery –** For medical equipment, Philips proactively engages with its customers to responsibly take care of the equipment at end-of-use. When refurbishment or parts recovery from returned equipment is not feasible, these systems are locally recycled to ensure they do not end up in landfill. This local recycling happens through the Certified Global Recycling network, from which documentation is received on the total material weight recycled. Material weight is documented and then aggregated. This provides an example of primary data collection used to calculate the % actual recovery.
- → **Secondary data collection for % actual recovery –** Products are, however, not always returned, especially consumer products as consumers discard them at the end of their useful life and national collection and recycling schemes eventually process them. The weight of recycled consumer products is estimated by multiplying the weight of products put to market (stemming from the Philips Environmental Profit and Loss Account –EP&L) with the EU WEEE recycling rates. This is similar to the methodology used for environmental footprint determination at end-of-life. This provides an example of the secondary data collection to use to calculate the % actual recovery.

This has led to an estimation of 475 tons of medical equipment locally recycled through the certified Global Recycling Network, and 11,800 tons of products (in WEEE category 5) and packaging from Personal Health Business Units recycled in the EU.

Using these data sources provides Philips with a way to calculate the recycling rate of its products. For consumer products, each EU member state provides country-level WEEE recycling rates. For medical equipment, it is not possible to derive recycling rates through the WEEE categories as the applicable categories include a variety of products and associated recycling rates may therefore not be fully accurate.

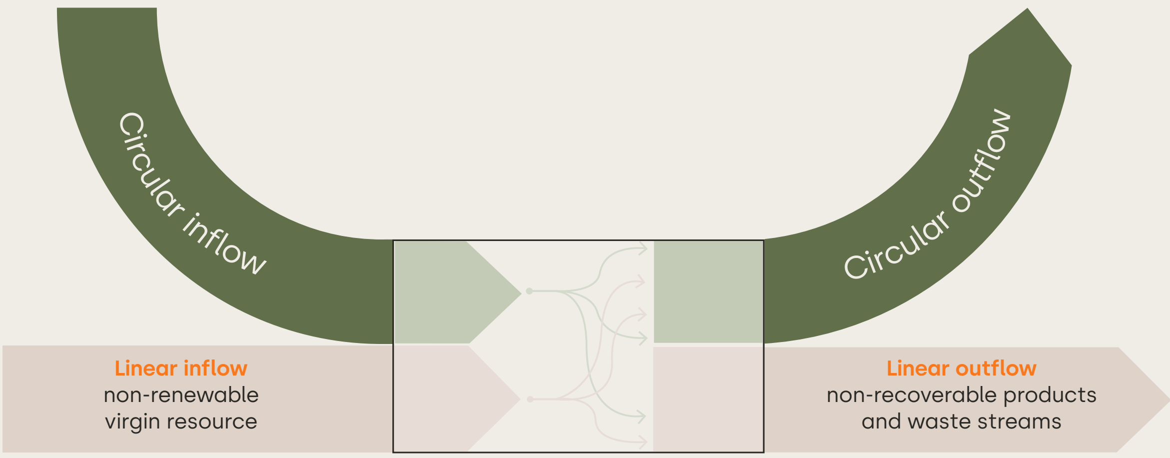
Internal data

In the data collection phase, companies may look for internal data sources within their organization. The availability of internal data can vary significantly depending on the nature of the company's operations. For instance, a manufacturing company may have data on the materials contained in their products, which is crucial for determining the circular inflow or on product design, which is relevant in determining the recovery potential. On the other hand, a retailer who is not involved in the manufacturing process is less likely to have this type of data available internally and will need to rely more heavily on their value chain partners for this information (see paragraph above).

It is important to note that even if a company has internal data available, it may not be sufficient for conducting a comprehensive CTI assessment. In such cases, it may be necessary to consult external data sources from value chain partners, industry databases and other relevant sources to supplement the internal data.

Figure 6 offers guidance on where to look for internal data. It is important to note that this is not an exhaustive list and that departments and their responsibilities can vary from one company to another.

Figure 6: Availability of internal data for CTI's key intervention points



% circular inflow	% recovery potential	% circular outflow
→ Procurement	→ Research & Development	→ Sales
→ Supply chain management	→ Design and engineering	→ After-sales services
→ Research & Development	→ Innovation and technology	→ Logistics and distribution
→ Design and engineering	→ Manufacturing and production	→ Waste management
→ Innovation and technology	→ Quality Assurance and Testing	→ EoL Partner management
→ Manufacturing and production		→ Internal repair department

Level of detail of collected data

Companies can collect data to inform the CTI indicators at different levels: **material, component or product level**. The level of detail chosen for the assessment depends on several factors, including the availability of data at a particular level and the desired outcome of the assessment. For instance, a retail company may not be able to identify every material contained in electronic devices to determine the % circular inflow. On the other hand, an OEM or brand may want to assess the recovery potential of its electronic devices through repair. This makes assessing the recovery potential more useful on the product then the material level. Table 10 provides some examples of how companies can collect and structure data at different levels to prepare for Step 4 – Calculate. Refer to the different activities for further examples of calculations.

Table 10: Data collection examples

→ **Example 1:** Collecting data for % circular inflow at a material level for an electronic device

Flow name	Category	Flow type	Critical material	Mass (Gr)	Non-virgin – renewable (circular) %	Non-virgin –non-renewable (circular) %	Virgin – renewable (circular) %	Virgin – non-renewable (linear) %
Magnesium (Mg)	INFLOW	material	X	780	0	50	0	50
Borosilicate glass	INFLOW	material		440	0	0	0	100
Inorganic glass	INFLOW	material		374	0	0	0	100
Polycarbonate (PC)	INFLOW	material		334	0	36	0	64
Acrylonitrile Butadiene Styrene (ABS)	INFLOW	material		287	0	36	0	64
Aluminum (Al)	INFLOW	material	X	198	0	50	0	50
Lithium cobalt oxide (LiCoO2)	INFLOW	material	X	170	0	0	0	100
Copper (Cu)	INFLOW	material		120	0	50	0	50
Iron (Fe)	INFLOW	material		86	0	50	0	50
PVC	INFLOW	material		54	0	36	0	64
Total				2.843	0	29%	0	71%

→ **Example 2:** Collecting data for % circular inflow on component level for an electronic device

Flow name	Category	Flow type	Critical material	Mass (Gr)	Non-virgin – renewable (circular) %	Non-virgin –non-renewable (circular) %	Virgin – renewable (circular) %	Virgin – non-renewable (linear) %
Screen	INFLOW	Component		440	0	80	0	20
Back cover	INFLOW	Component		780	0	80	0	20
Tiles	INFLOW	Component		120	0	0	0	100
Mousepad	INFLOW	Component		100	0	0	0	100
PCB	INFLOW	Component		250	0	22	0	78
Total				1.690	0	61%	0	39%

→ **Example 3:** Collecting data for % actual recovery on component level for an electronic device

Flow name	Category	Flow type	Critical material	Mass (Gr)	Actual recovery %	Source	(Default) Recovery potential %
Screen	OUTFLOW	Component		440	60	Own closed loop process company X	70
Back cover	OUTFLOW	Component		780	70		70
Tiles	OUTFLOW	Component		120	0		70
Mousepad	OUTFLOW	Component		100	0		70
PCB	OUTFLOW	Component		250	20		70
Total				1.690	51%		70%

% material circularity = Example 2 * Example 3 = 61% + (51% * 70%)/2 = 48%

Note: The % recovery potential is set at 70% based on teardown report created at full device level on the "recyclability of the device".

→ **Example 4:** Collecting data for % actual recovery on product level for an electronic device (based on product portfolio)

Flow name	Category	Flow type	Critical material	Mass (Gr)	Actual recovery %	Source	(Default) Recovery potential %
Laptop	OUTFLOW	Product		1.690	80	Own closed loop process company X	65
Hair dryer	OUTFLOW	Product		400	100		100
Vacuum cleaner	OUTFLOW	Product		4.400	80		86
Headphones	OUTFLOW	Product		280	40		70
Total				6.770	80		81%

Note: The % recovery potential is determined for the different products in the portfolio based on teardown reports by the OEM.

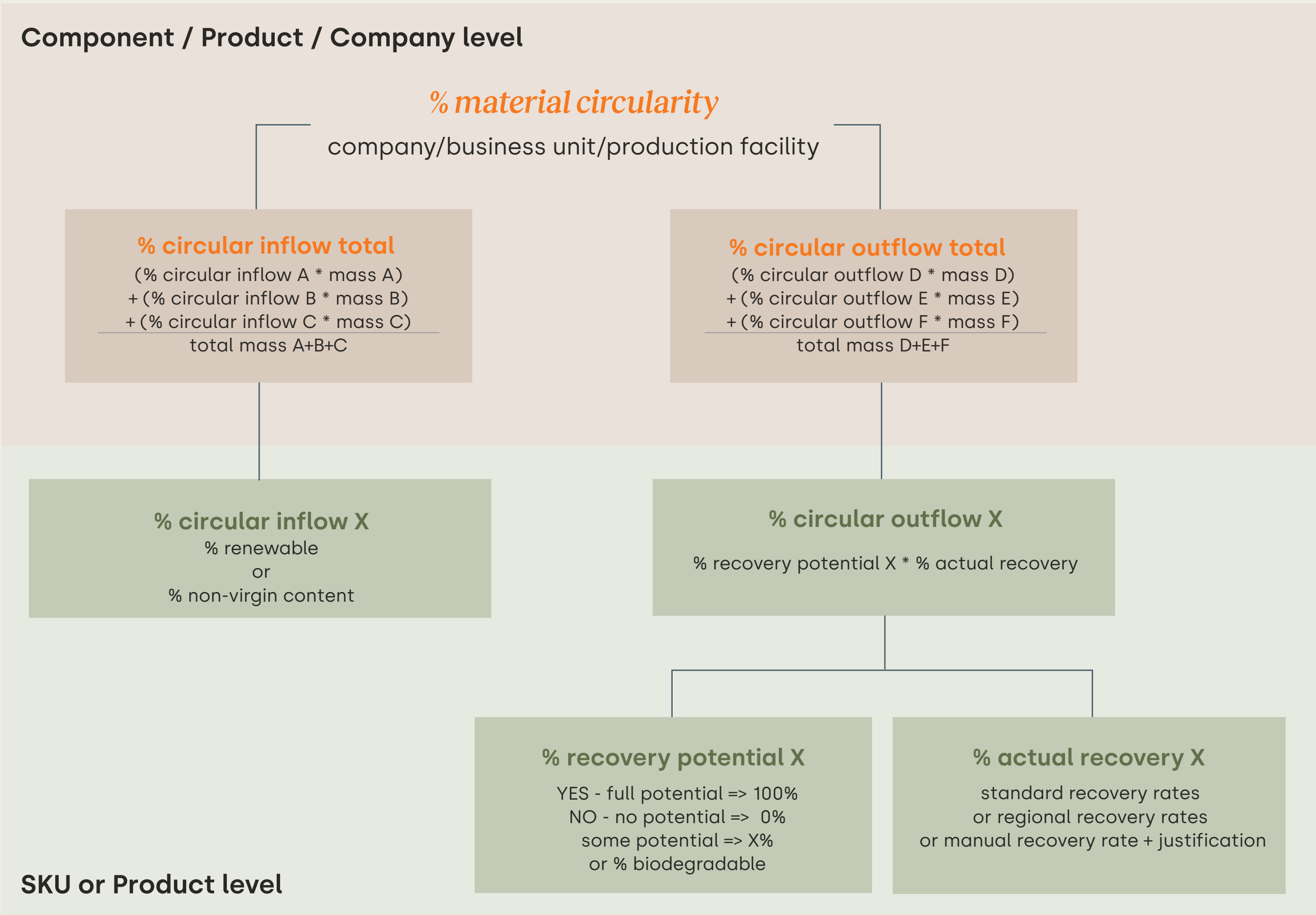
Step 4 – Calculate

Perform the calculations

After collecting all the data, the company can calculate the performance of the indicators. In this section, we present the different formulas used to calculate indicators to provide guidance on how to calculate the different indicators.

CTI is a methodology based on flexible system boundaries, meaning that the methodology is applicable at the component, product, business unit and company level. In line with this, it is important to understand how to move from one level to another. Figure 7 illustrates these variations in levels. For each of the four material circularity indicators, the next steps will clarify how to calculate them.

Figure 7: Calulating % material circularity



1 ***Close the Loop***

→ **% material circularity**

→ **% water circularity**

→ **% renewable energy**

% material circularity

Circular inflow

% circular inflow (per material flow) - renewable

To measure the renewable inflow, the company needs to measure the following aspects:

% circular inflow (per material flow) – non-virgin

To measure the non-virgin inflow (recycled or reused) flows, the company needs to measure the following aspects:

Virgin/primary flow – linear

For all inflows where the material has not been used before, the following formula applies:

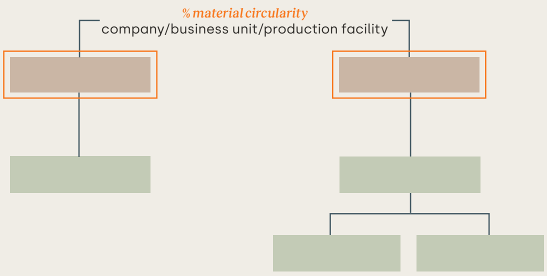
% circular inflow V = 0%

Non-virgin flow – circular

For all inflows where the material has been (partially) used before, for example via reuse or refurbish, the following formula applies:

% circular inflow NV = % recovered content

Once the company has calculated both inflows levels at component or product level, it is possible to aggregate them to have a view at the business unit or company level. In line with this, the company can apply the following formula:

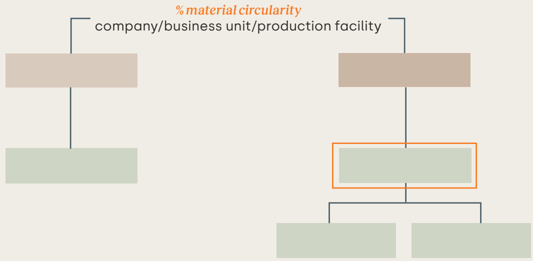


% circular inflow total

$$\frac{[(\text{\% circular inflow A} * \text{mass A}) + (\text{\% circular inflow B} * \text{mass B}) + (\text{\% circular inflow C} * \text{mass C})]}{\text{total mass of all inflows (A + B + C)}}$$

Circular outflow

% circular outflow reflects the combined effectiveness of the company to increase Recovery potential and to maximize actual recovery of its products. The company can apply the following formula to reflect this combined perspective:



% circular outflow X

% recovery potential X * % actual recovery X

% circular outflow (per material flow) – Recovery potential

The measure the Recovery potential rate, the company needs to measure the following aspects:

No recovery possible – linear

For all outflows, where the design does not enable any recovery potential, the following formula applies:

% circular outflow NR = 0%

Partial recovery possible – partially circular

For all outflows, where the design enables some recovery potential, the following formula applies:

% circular outflow NR = % recovery potential

Partial recovery possible – circular

For all outflows, where the design enables full recovery potential, the following formula applies:

% circular outflow R = 100%

The aim is to provide some guidance to indicate a possible recovery rate in line with each design principle. The recovery potential rates are guidelines to better understand the weight of each design practice. They can be added together.

% circular inflow (per material flow) – non-virgin

To measure the non-virgin inflow (recycled or reused) flows, the company needs to measure the following aspects:

Virgin/primary flow – linear

For all inflows where the material has not been used before, the following formula applies:

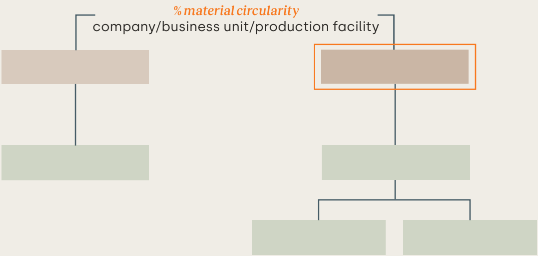
% circular outflow A = % recovery from new

Since many outflows are possible for a company, for each outflow the possible ways are presented to measure it. Examples of outflow are:

Waste creation: for all outflows that can be considered as waste or as left over from the production, where the company has control, the company should add waste to the measurement and apply the formula shown above.

Take-back system: for all outflows that can be considered as part of a take-back scheme, where the company has control, the company should add the flow to the measurement and apply the formula shown above.

Once the company has calculated both outflow levels at the component or product level, it is possible to aggregate them to have a view at the business unit or company level. The company can apply the following formula to reflect this aggregated level:



% circular ouflow total

$$\frac{[(\%\ \text{circular outflow A} * \text{mass A}) + (\%\ \text{circular outflow B} * \text{mass B}) + (\%\ \text{circular outlow C} * \text{mass C})]}{\text{total mass of all outflows (A + B + C)}}$$

% water circularity

To calculate the water circularity rate, the company needs to measure the following aspects:

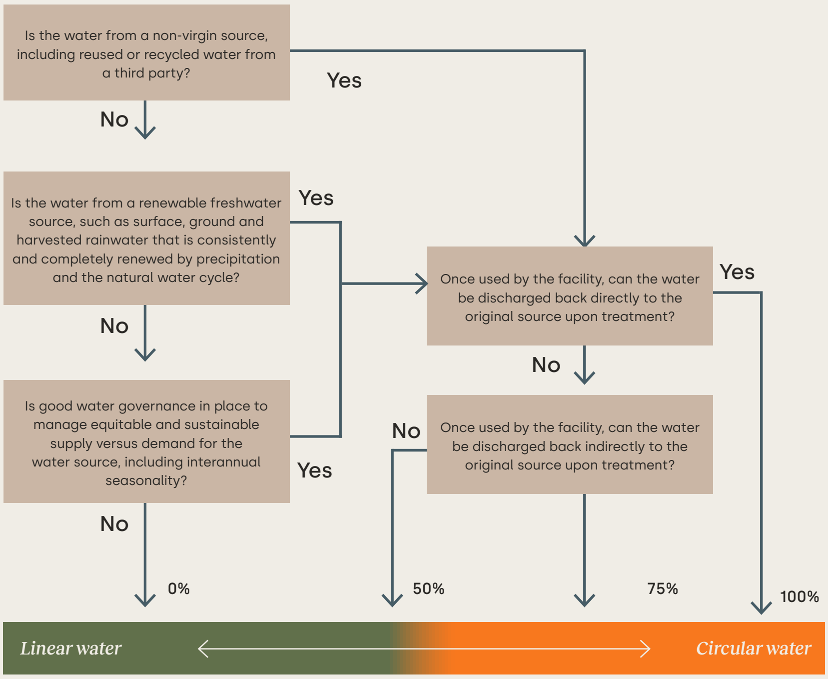
Water inflow

For all water inflows, the following formula applies to define the level of water circularity:

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

To support companies in defining the level of water circularity for inflow, CTI proposes the following schema:

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



Water outflow

For all water outflows, the following formula applies to define the level of water circularity:

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

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

- → Water outflow is circular if other sites (offsite) recycle it; this includes drinking water supply to communities in the basin.
- → 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.
- → Product water is circular if returned to the local watershed at a quality that makes it readily available for environmental, social, agricultural or industrial purposes.

% renewable energy

For all energy flows, the following formula applies to define the level of renewable energy:

$$\frac{\text{Renewable energy (annual consumption)}}{\text{Total energy (annual consumption)}} \text{ X } 100$$

2 *Optimize the Loop*

→ % critical material

→ % recovery type

→ onsite water circulation

→ actual lifetime

% critical material

For all critical materials, the following formula applies to define the percentage of critical material:

$$\frac{\text{Mass of inflow defined as critical}}{\text{Total mass of linear inflow}} \text{ X } 100$$

% recovery type

The company needs to identify what happens to its outflow in line with actual recovery. For this indicator, it is important to understand for the various outflows provided (repair, reuse, refurbish, recycle) and what happens to the outflow.

% on-site water circularity

For all on-site water flows, the following formula applies to define the percentage of on-site water circularity:

$$\frac{\text{(Q water use - Q total water withdrawal)}}{\text{Q total waster withdrawal}} +1$$

Actual lifetime

To measure the average lifetime of components or products, the company needs to measure the following aspects:

Product actual lifetime

- → This requires companies to understand the actual lifetime of their component or product.
- → Average product actual lifetime.
- → This requires companies to understand the average lifetime of a component or product in a similar component or product category for comparison.

Actual Lifetime Indicator

$$\frac{\text{Component or product actual lifetime}}{\text{Average component or product actual lifetime}}$$

3 *Value the Loop*

→ **circular material productivity**

→ **CTI revenue**

Circular material productivity

$$\frac{\text{Revenue}}{\text{Total mass of linear inflow}}$$

CTI revenue

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

For this indicator, the following formula applies:

CTI revenue product A
+ CTI revenue product B
+ ....

4 *Impact of the Loop*

→ **GHG impact**

→ **nature impact**

GHG impact

Inflow

Companies should analyze the information derived from the Impact of the Loop module considering the % material circularity indicator. The result of the calculation is the amount of GHG emissions the company can save if the materials go from the current % recycled content to increased % recycled content. The following formula should be applied:

$$(M_t{*}GHG_t) - (M_t{*}GHG_t) - (M_t{*}GHG_t)$$

Or the formula for the percentage of actual savings:

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

Outflow

Companies should analyze the information derived from the Impact of the Loop module considering the % material circularity. For the outflow, the results of the calculation are the amount of GHG emissions the company can save if the materials go from the current % of recovery to 100% recovery via recycling, remanufacturing or reuse. The following formula should be applied:

$$(M_t{*}GHG_{xl}) - (M_t{*}GHG_{xl})$$

Or the formula for the relative savings:

$$\frac{(M_{xr}{*}GHG_{xl}) - [(M_t{*}GHG_t)]}{((M_t{*}GHG_{xl}) * GGHG_t)} \times 100$$

Formula explanation

- → **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

Nature impact

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

$$(M_{xr}{*}\text{extent}){*}(M_{xrp}{*}\text{condition change}){*}(M_t{*}\text{significance})$$

For further explanation of how this indicator is calculated in CTI, please refer to **CTI v4.0**, page 72.

Step 5 – Analyze

This section delves into the analysis of calculation results obtained in Step 4 – Calculate, concentrating on two primary aspects:

- **Current performance:** CTI can serve as a measure of existing performance levels. Simultaneously, the exploration of potential improvement involves identifying the business percentage still operating on a linear model. Delving deeper into the underlying indicators is crucial to understand the measures needed for improving circular performance.
- **Performance over time:** tracking performance over time can yield valuable insights, enabling companies to assess their progress related to predefined objectives, goals and targets, etc. This is based on the execution of multiple assessments with the framework to gain insights into improving or decreasing circular performance by circular measures taken.

During the analyze phase the company identifies opportunities to improve circular performance.

1 *Close the Loop*

- → % material circularity
- → % water circularity
- → % renewable energy

% Material circularity

Inflow

Two different levers can influence the circular performance of the topic under scope: mass of flows and the circularity of flows.

The mass of flows

Prioritizing heavier material streams can significantly improve circularity performance, as weight-based indicators suggest that substantial material flows have a greater impact. A company's focus on reducing the use of critical or other materials may lead to a different approach. While reducing the use of these materials may be the initial objective, it may not have as significant an impact on circularity performance as prioritizing heavier materials. Therefore, when analyzing materials, it is essential to consider their weight and impact on performance.

The circularity of flows

Technical cycle: The circularity of the inflow in the technical cycle depends on non-virgin inflow used in the chosen scope of assessment. During the analyze phase, a company will analyze the material streams and will consider improvement opportunities by replacing virgin material with either non-virgin or renewable bio-based material.

Biological cycle: When a company is analyzing opportunities for improvement to have more circular inflow in the biological cycle, different options exist. A strategy for improving circular inflow in bio-based streams includes increasing the proportion of sustainably grown/managed material, e.g., by using sources from certified renewable sources. Common items like phone cases or laptop shells, typically made of plastic, can be replaced with renewable bio-based plastics. These must be sourced from environmentally friendly materials like corn or sugarcane, reducing the dependency on non-renewable resources.

While renewable materials, as part of the biological cycle, are considered one of the two types of circular inflow in CTI, we have intentionally excluded them from the rest of this guidance as materials from the biosphere are not expected to have a significant impact on the production of electronic products. For more context refer to the Circular Electronics System Map.

Outflow

The outflow comprises of two points of influence: recovery potential and actual recovery.

Recovery potential

Enhancing recovery potential centers on design optimization. During this phase in the assessment, a company looks for design improvement opportunities to increase recovery potential. For instance, a company can design laptops to allow for easy disassembly, thereby facilitating repair, remanufacturing or recycling. Likewise, they can consider future use when designing phones, with a focus on extending product life cycles and ensuring repairability. Some options to achieve this are: modular design, creating easily replaceable parts to extend product longevity and offering the possibility of upgrading components like memory or storage to stay up-to-date with future technological advancements.

Actual recovery

To increase actual recovery, companies can consider various strategies, such as take-back schemes, which, could help boost actual recovery rates. Collaborating with third parties to increase circularity throughout the value chain can serve to improve actual recovery.

Improving the actual recovery depends on the type of valorization. For example, investing in advanced recycling technologies, such as processes for extracting valuable metals and components from discarded electronics. Additionally, companies may encourage innovative design strategies like modular electronics or upgradable electronics, which enable easy disassembly and component replacement.

% water circularity

To increase the circularity of water use, companies should consider ways to either decrease the use of water or improve water circularity. A company can, for example, improve water use in two ways:

1. Better demand management, reducing overall water use;
2. Substitute linear water in- and outflows with circular in- and outflows.

% renewable energy

This indicator shows the percentage of renewable energy used. Improvement opportunities are:

- → Decreasing overall energy consumption;
- → Substitute fossil fuels with renewable alternatives.

2 *Optimize the Loop*

→ % critical material

→ % recovery type

→ actual lifetime

→ on-site water circulation

% critical material

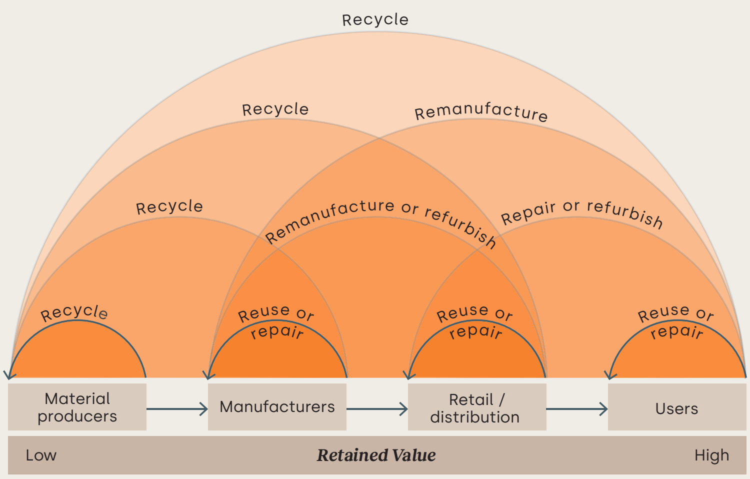
A company can have multiple critical materials in its inflow such as cobalt or nickel (critical material defined by the EU[21]). Criticality of materials is determined by the EU Critical Raw materials list and US Critical Minerals List but could be extended by materials deemed critical to operations by the company based on size on total consumption, revenue dependency and relative criticality of the material.

A company can mitigate its risk by replacing the critical materials with alternative, non-critical materials with the same or similar functionality whenever possible. Therefore, companies should analyze if alternatives are available that they can substitute for the critical materials.

% recovery types

Companies should strive to employ recovery strategies that contribute to preserving the value of inputs longer, such as reusing or remanufacturing. The opportunities for a company to employ higher value recovery strategies largely depends on its business model and its position in the value chain. We encourage companies using CTI to ensure their outflows (products, by-products or waste) retain the highest possible value by prioritizing reuse over recycling, for example, whenever possible.

Figure 8: Recovery types and retained value



Actual lifetime

By monitoring CTI's Actual lifetime indicator, companies can improve their effectiveness in slowing down resource loops. **It is possible to extend the actual lifetime of the product if it has been designed to extend performance throughout both technical and functional lifetimes**. While a product's technical lifetime is inherent, its functional lifetime is determined by the conditions surrounding the product. A company can lengthen the actual lifetime by designing both the products and product ecosystems to enable maximum technical and functional lifetimes. This is achievable by improving product design, focusing on longevity, reliability, modularity, ease of maintenance, upgradability, easy disassembly and component recovery, as well as the availability of spare parts, guidance on repair and offering repair services.

CTI revenue

This indicator gives insights into:

- → 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.

To improve this indicator companies can think of:

- → Innovating new circular products;
- → Increase the circularity of existing products;
- → Driving sales of more circular alternatives over less circular alternatives to increase revenue.

3 *Value the Loop*

→ circular material productivity

→ CTI revenue

4 *Impact of the Loop*

→ GHG impact

→ nature impact

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.** Additionally, it is relevant to compare a decrease or increase in circular material productivity externally. 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.

GHG impact

Companies should examine the data gathered from the Impact of the Loop module in conjunction with the percentage of material circularity. This interplay of enhanced material circularity and potential for emissions savings can guide companies in prioritizing solutions that deliver highest gains from both a resource use and greenhouse gas (GHG) emissions reduction perspective.

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

Step 6 – Prioritize

The knowledge obtained through the CTI assessment highlights which flows offer the most significant scope for improvement. To use this data to make informed decisions and set priorities, it's essential to understand how circular performance correlates with risks a company may incur by continuing to operate on a linear business model (i.e., linear risks). By evaluating the company's exposure to risks and subsequently assessing opportunities through a business case, companies can begin to prioritize their actions strategically.

Identify opportunities

The insights gathered on circular performance indicate which flows have the greatest potential for improvement. 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 subsequently evaluating opportunities via a business case, companies can start prioritizing actions. For this section, we refer to **WBCSD's Linear Risks report**, which explains circular risks and opportunities.

Identify linear risks and circular opportunities

Linking the indicators used in the assessment to linear risks and circular opportunities can highlight risks and opportunities. See Table 12 for an indication of possible risks and opportunities per indicator.

Table 11: Possible risks and opportunities per indicator (1/4)

Type of risk		Material	Component/ Product	Business unit	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**	Creating partnerships with recyclers to secure a steady stream of recycled materials	Create collaborations with value chain partners to recover component / products for a second life cycle	Shifting consumers demand towards second-hand devices/ products	Subsidies for renewable (certified) or non-virgin resources
	Risk	Resource scarcity driving up costs of raw materials	Supply chain failures, mostly relevant due to the globalized nature of the industry	Negative brand perception due to non-sustainable practices	More stringent requirements for consumer eco design (Ecodesign for Sustainable Products Regulation (ESPR)), batteries (EU Battery Directive)
% circular outflow	**Opportunity**	Valorizing waste as a secondary resource	Attracting and retaining talent	New business models such as product as a service or take-back systems	Subsidies and incentives for business model innovation and valorization of non-virgin flows
	Risk	Trade bans on transporting electronic waste across borders for recovery	Internal process failures	Right to Repair movement	Mandatory reporting to open loop collection and recycling schemes as mentioned in CSRD – ESRS E5

Table 11: Possible risks and opportunities per indicator (2/4)

Type of risk		Material	Component/ Product	Business unit	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
% water circularity	**Opportunity**	Attract interest with new materials and processes reducing water consumption	Awareness of manufacturing methods and processes with reduced water demand	New innovative technologies for water	Potential for more secure water rights due to demonstrable sustainable management
	Risk	Excessive water use could lead to increasing operational costs, especially in regions where water scarcity is a problem	Water shortages disrupting operations and unforeseen mitigation cost	Over-reliance on water resources could lead to business continuity risks	Upcoming tightening of regulations with rising water scarcity
% renewable energy	**Opportunity**	Strategic investment in renewable energy sources can open new market opportunities	New partnerships	Decreasing cost of renewables	Greater access to renewable resources as a result of tightening renewable portfolio standards across jurisdictions
	Risk	Dependence on non-renewable energy sources could lead to unstable energy costs	Continual use of non-renewable energy sources can increase operational costs and carbon footprint	Relying heavily on non-renewable energy sources can drive negative stakeholder perception and potential divestment	More prescriptive procurement and disclosure rules for companies, whether imposed by investors or regulators
% critical material	**Opportunity**	Reducing use, finding alternatives or recycling critical materials would make the supply chain more resilient, potentially reduce costs and open new markets	Avoided upstream risks with substitution of critical materials	Pursuing alternative materials, innovative design or technological solutions to reduce dependencies on critical materials could lead to sustainable business growth	(New) government policies on protecting markets and extension of mining operations for critical materials.
	Risk	Dependence on critical raw materials which are scarce or subject to geopolitical risks could lead to unstable costs and supply chain disruptions	Using a high percentage of critical raw materials could lead to operational risks due to potential shortages, high costs or challenges in sourcing such materials	A heavy reliance on internationally sourced critical materials could lead to geopolitical risks and potential challenges to business continuity	Sourcing rules and new regulations such as the Critical Raw Material Act in Europe

Table 11: Possible risks and opportunities per indicator (3/4)

Type of risk		Material	Component/ Product	Business unit	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
CTI revenue	**Opportunity**	Diversifying company's revenue streams to include circular models such as leasing, repairing or refurbishing can offer a new way to generate a more steady and sustainable revenue	Streamlining operations to support circular practices can create cost-savings and efficiencies, resulting in increased circular revenues	Brand equity and reputation benefits Consolidation of the brands and the creation of a real second-hand market	Preparedness for reporting and disclosure Regulations can level the playing field for all brands to ensure all are part of the circular solution
	Risk	Circularity's higher costs require more customer engagement to retain revenue The lack of insights responding to investor inquiries	Dependency on the traditional production and disposal model could lead to inefficiencies and wastage	Non-diversified revenue streams heavily reliant on a linear economy could risk fiscal stability in a shifting market	Upcoming regulations on more linear products
Actual lifetime	**Opportunity**	Market expansion opportunities Reduction of manufacturing and 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)
	Risk	Producing low-durability products can risk brand image and customer loyalty, leading to the potential decline in market share	Products with short lifespan may result in more frequent production cycles, leading to higher production costs	Short-lived products could result in lower customer satisfaction and negative impact on business reputation	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	Streamlining operations to reduce emissions can create efficiencies and potential cost-savings	Providing alternatives with a lower carbon footprint	Benefits for products offerings with lower carbon footprint More favorable performance under potential mandatory product labelling and scoring schemes
	Risk	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	Ability to meet consumer demand for lower impact products	Ability to meet waste GHG reporting requirements

Table 11: Possible risks and opportunities per indicator (4/4)

Type of risk		Material	Component/ Product	Business unit	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
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 for packaging with a lower impact on biodiversity to (new) clients	Advance preparation for compliance with new regulatory frameworks for biodiversity, such as the EU's CSRD
	Risk	Failure to meet increased demand for sustainably sourced materials, in particular the critical materials	Environmentally damaging operations may lead to inefficiencies and increased costs, particularly if regulations tighten for environmental protection	Businesses not considering their impact on nature may face increased scrutiny from investors, affecting their valuation and ability to raise capital	Non-compliance with environmental laws and regulations can lead to legal penalties and damage to the company's reputation

Linear risk assessment and prioritization

Companies should formulate and prioritize actions considering 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:

1. Scenario analysis

Outline circular economy scenarios:
- → No regulatory or market pressure
- → Diverse national or regional regulatory pressure
- → Strong global market and regulatory pressure

2. Establish risk severity

Establish the severity of linear risks:
- → Threat prioritization
- → Vulnerability prioritization

3. Define and assess action roadmaps

Define and assess action roadmaps based on:
- → Ability to mitigate linear risks
- → 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**, such as how will the playing field remaining the same affect the company?
- → **Diverse national or regional regulatory pressure**, such as how will national or regional targets affect the business of a company in the future?
- → **Strong global market and regulatory pressure**, such as how will robust combined global trends (technology, market, regulations) affect the business of the company?

2. Establish risk severity threat and vulnerability assessment

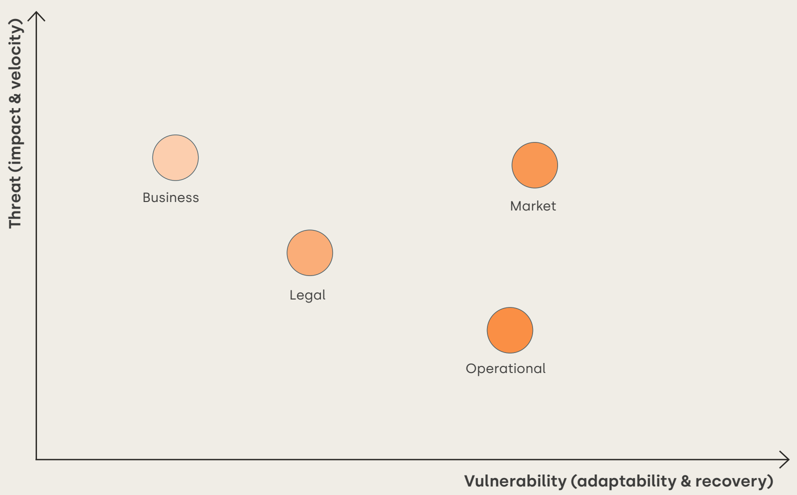
In this step, companies use the information gathered from the scenario analysis to rank and prioritize linear risks. Common criteria for risk prioritization are severity of adverse impact and likelihood. Relying on these factors alone might limit the accuracy of the prioritization. We suggest using two more-elaborate criteria defined by the COSO Enterprise Risk Management—Integrating with Strategy and Performance (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).[22]

Companies can visualize the above-mentioned risk factors in one overview to enable formulation of potential actions and final prioritization. Figure 9 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 purpose and can be made more specific by including all linear risk subcategories. The visualization supports in prioritizing which risk to address first. Based on this prioritization, in combination with the insights obtained during the analysis phase, companies can plan the roll out of actions and next steps.

Figure 9: Identifying risks and plotting along threat and vulnerability



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.
Start 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 they take different actions 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 like writing a story, or can visualize it graphically, for example as a timeline with different future events. Use the quantitative and qualitative factors defined in step 1 to highlight the effects achieved in each action roadmap.

Step 7 – Apply

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.

Companies should therefore do the following:

Formulate targets

Based on the analysis, the potential opportunity for improvement has become apparent. The prioritize phase has identified the risk and opportunities to address. When combined, this information provides relevant evidence to formulate SMART (specific, measurable, ambitions, relevant, time-bound) targets.

Roll out actions

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

1 *Define what needs to happen:*

The target gives direction on what needs to happen. As described in the analysis section and the industry targets 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.

2 *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 in the roadmap to ensure the alignment of assessment cycles with the intermediate targets.

3 *Define who needs to take action:*

To ensure action, it is necessary to identify an owner to drive action. Table 11 in CTI v4.0 lists the possible actions from the analyze phase, with the relevant departments internally, the external parties to consider and considerations to consider 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 CTI. 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.

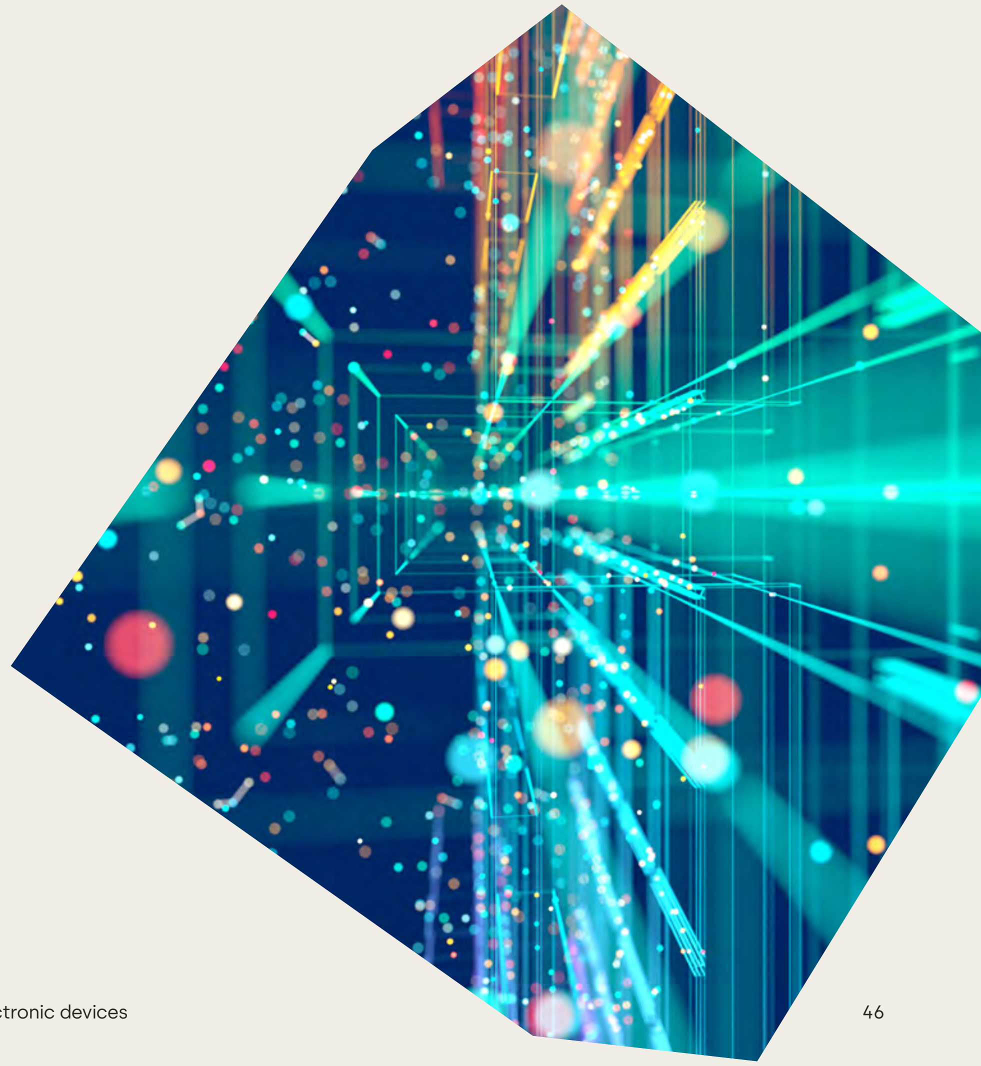
CTI electronics sector guidance – Part 2
→ *Value chain-specific CTI application*

03.

This section provides insights into how companies can apply CTI to electronic devices based on their position in the value chain. Depending on a company's position in the electronics value chain or business model, the selection of indicators and data retrieval will vary.

To address the diverse requirements of different positions within the electronics value chain this section looks at each value chain activity individually and provides insights into CTI steps 1–3.

Part 2
Value chain-specific CTI application *46*



03. Part 2— Value chain-specific CTI application
→ *Raw material extraction*

Value chain activity 1: Raw material extraction

Raw material extraction

A company that extracts raw materials for electronic devices specializes in the extraction and processing of natural resources used in the production of electronic products. These resources may include metals such as copper, gold, silver and palladium, as well as rare earth elements. The company may operate mines or other extraction facilities to extract these resources from the earth or purchases raw materials from other suppliers. As well as be a smelter, pure sales company or agent.

Due to the unique nature of the extracting and procuring of virgin resources, **a raw material extraction company will approach CTI differently compared** to other companies in the value chain.

This guidance considers the parties listed in Table 12 as potential (raw) material extraction companies with the aim to include a broader range of materials suppliers. Note that the table is not exhaustive.

Table 12: Examples of raw material extraction companies

Mining company	→ responsible for sourcing specific ores that contain necessary raw materials such as bauxite for aluminum, cassiterite for tin and ores with silver or gold
Rare earth element extraction companies	→ responsible for extraction of rare earth materials such as copper, magnesium, cobalt and nickel[23]
Metal refining companies	→ after mining, raw materials usually need further refining to extract the specific metal required for manufacturing
Material processing companies	→ responsible for carrying out processes like melting, refining or other treatments to prepare the raw materials for use in manufacturing
Material distributors	→ once extracted, treated and refined, the materials are shipped to manufacturers through various channels; the material distributor could be the primary contact for the manufacturer
Material extraction company (recycling company)	→ recycling products/components to material level, potentially possessing data on the circular inflow use by the manufacturing company (also included as a separate activity in the value chain)

Recommendations for data collection

A raw material extraction can obtain primary data for CTI calculations from various sources. Data may originate from multiple up- and downstream value chain partners.

In Figure 10, a raw material extraction company will reach out to the manufacturing party for data related to the fate of materials (e.g., critical) supplied for the calculation of the circularity of its outflows.

Since raw material extraction companies' core business is the extraction of virgin resources or the harvesting of bio-based materials, these companies will focus on CTI indicators that can deliver the most benefits from a circularity perspective.

In terms of inflow, extraction operations are linear. Starting with the extraction of virgin materials, the progression follows a simple, one-way route to the introduction of these virgin materials into the value chain. **The outflow, in contrast, could be circular and linear. The outflow is circular if the subsequent company in the value chain uses the raw material extracted by the company for a component or product.**

Variations exist in the perception of the raw materials in the value chain. For example, what a player downstream in the value chain might see as a linear process – such as the extraction, use and then discarding of the raw materials – a raw material extraction company may see it as circular outflow, since the materials are used in a manufacturing process that follows.

Figure 10: Data related to the fate of materials supplied for the calculation of circularity outflows

	Own Operations	Downstream
Flow	**Company boundary**	**Outflow** (← **Data Flow**)
Activity	**Raw Material Extraction**	**Component, contracted and OEM manufacturing**
Potential data points	→ Material weight → Material specifications → Critical materials → Material waste resulting from extraction processes	→ Product/component quantities → Product/component weight → Material specifications → Critical materials → Recovery potential → Waste
Datal point level	Material level	Product or component level
Potential data sources	→ Internal data bases → Laboratory and testing reports → Regulatory fillings	→ Procurement and sales data → Material safety data sheets (MSDS) → Bill of Materials (BOM) → Disassembly or repair reports → Waste reports

Raw material extraction companies play a crucial role in the value chain as they possess valuable knowledge about the materials processed into components and products. By providing this data to other companies throughout the value chain, they can support transparency and accountability for their customers.

A raw material extraction company should tailor the structure of the CTI assessment to reflect the unique nature of its operations. The understanding that the company operates within a distinct part of the value chain, with a linear inflow and a circular outflow of resources and that recovery is an important contributing factor to the operation's circularity potential, can guide the company in conducting a more accurate, relevant and effective CTI assessment.

Value chain activity 2: Manufacturing

Manufacturing

Manufacturing companies are responsible for designing, manufacturing or placing orders with contracted manufacturers and assembling electronic devices and components used in electronic devices. They source raw materials from various suppliers to manufacture electronic components such as PCBs, microprocessors, memory chips, sensors and displays. They further conduct quality control and testing as integral parts of their product development process. These companies either provide components to other manufacturing companies that produce end-user products or produce end-products themselves.

Through the manufacturing lens

Manufacturing can take place at different companies/partners, for an entire electronic device or single components. In this guidance, we have split manufacturing into three different scopes. We use these scopes throughout to provide guidance on how to perform CTI steps 1–3.

→ *Component manufacturing:* A company that manufactures components for electronic devices produces a variety of electronic components, including PCBs, microprocessors, memory chips, sensors and displays. It might use advanced manufacturing processes and technologies such as 3D printing and automated assembly lines and conduct R&D processes to design new components. The company then sells these components to manufacturers to produce a wide range of end-user electronic devices. Taiwan Semiconductor Manufacturing Company (TSMC) is an example of a component manufacturer that produces semiconductors for electronic device manufacturers.

- *Contracted manufacturing:* A contracted manufacturer for electronic devices is a company hired by another company to produce electronic devices or components on their behalf. They are responsible for the manufacturing process, including sourcing materials, assembly and quality control and may use advanced manufacturing technologies to produce high-quality products. The contracted manufacturer works closely with the hiring company to ensure that the final product meets their specifications and requirements. Foxconn is an example for one of the largest contract manufacturers globally and has partnerships with major technology companies, including Apple, Dell, HP and others.
- *Original equipment manufacturer (OEM) (manufacturing & assembly):* An OEM for electronic devices specializes in the entire process of designing, producing and assembling electronic products used by end-consumers. This includes everything from product development to manufacturing, as well as quality control and testing. This may include smartphones, tablets, laptops, smart home devices and other electronic products.

Different situations exist in which the OEM is only responsible for the design of the product but no materials are entering or leaving the company boundaries. In these situations, this chapter supports in using the manufacturing lens to understand which steps to take to perform the assessment.

Step 1 - Scope

Define the scope of the assessment by answering key questions explained in the first part of this document: **Part 1 – General CTI explanation.**

Step 2 - Select

CTI offers a menu of indicators that enable the company to answer the questions from the scoping step. The tables below offer guidance on selecting indicators for specific activities based on their materiality and usefulness in providing insights, considering the unique business context of each activity.

We make the following distinctions between the different indicators:

- **Required:** Include the indicator as part of the % material circularity (Close the Loop);
- **Recommended:** We recommend the inclusion of the indicator in the assessment, since the assessment provides relevant insights for the activity in scope;
- **Optional:** The indicator is optional; companies can decide to include it based on their sustainability and business objectives.

Appendix II – Manufacturing provides an explanation of the indicators and the reasoning behind their classification as required, recommended or optional.

Table 13: Suggested indicators for manufacturing

Close the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% material circularity	Required	Required	Required
% water circularity	Recommended	Recommended	Recommended
% renewable energy	Recommended	Recommended	Recommended
Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% critical material	Recommended	Recommended	Optional
% recovery type	Recommended	Recommended	Recommended
On-site water circulation	Optional	Optional	Recommended
Actual lifetime	Recommended	Recommended	Recommended
Value the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Circular material productivity	Optional	Optional	Not Recommended
CTI revenue	Optional	Optional	Optional
Impact of the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
GHG impact	Recommended	Recommended	Recommended
Nature impact	Optional	Optional	Optional

Step 3- Collect

Step 3 outlines best practices for data collection action for % material circularity, % critical material, % recovery type and actual lifetime.

To perform a CTI assessment, manufacturers of electronic devices can gather primary data from various up- and downstream value chain partners. Collecting primary data ensures high accuracy and reliability in the assessment. If primary data is unavailable, manufacturers can rely on secondary sources like external databases or publications.

Depending on the company's position in the value chain, they may need to request data from multiple partners to perform the assessment. Figure 11 shows potential sources of primary data, including raw material sourcing companies for inflow data and retailer, preparation for reuse companies and recyclers for outflow data.

Calculating the selected indicators requires multiple data points. **A company must carefully consider which data to include or exclude and the level of granularity.**

Figure 11: Data related to the fate of materials supplied for the calculation of circularity outflows

	Upstream		Own Operations	Downstream			
Flow	Inflow Data Flow →		Company boundary	Outflow ← Data Flow			
Activity	**Raw Material Extraction**	**Preparation for reuse services**	**Raw Material Extraction**	**Retail and distribution**	**Use**	**Preparation for reuse services**	**Recycling**
Potential data points	→ Material weight → Material specifications → Critical materials → Material waste resulting from extraction processes	→ Product/component weight → Product/component specifications → Recovery potential	→ Material weight → Material specifications → Critical materials → Material waste resulting from extraction processes	→ Actual recovery	→ Actual lifetime → Actual recovery	→ Product/ component weight → Recovery potential → Actual recovery	→ Material weight → Critical materials → Actual recovery
Datal point level	Material level	Product or component level	Material level	Product level	Product level	Product or component level	Material level
Potential data sources	→ Internal data bases → Laboratory and testing reports → Regulatory fillings	→ Material safety data sheets (MSDS) → Bill of Materials (BOM) → Disassembly or repair reports → Waste reports	→ Internal data bases → Laboratory and testing reports → Regulatory fillings	→ EoL service providers → Waste handler reports	→ Customer surveys	→ Disassembly or repair reports → Waste reports	→ Recycling reports → Material tracking sheets → Certificates → Laboratory and testing reports → Waste reports

CTI use case – Philips

Products that are challenging to recycle make it harder to recover value from them at the end of their useful lives. There is a growing regulatory focus on circular design, including the recyclability of products. One of Philips 2025 ESG commitment is that the company will design all new product introductions in line with its internal EcoDesign requirements. Circularity is one of the four core focal areas of EcoDesign. The company developed a recyclability tool that uses product-specific data on the materials and the types of connections used to determine the recyclability rate.

- → Data on materials used comes from several sources, such as the bill of materials (BOM) and CAD drawings.
- → Data on the recyclability comes from recycling vendors and insights from experts.

Philips created an Excel-based tool that its businesses can use to assess the recyclability of products. The results indicate a % recyclability while also showing areas for further improvement. This % provides inputs to the % recovery potential in CTI, focusing on the future recoverability of products by design as well as its actual recycling rates.

1 ***Close the Loop***

→ To calculate: % material circularity

% circular inflow (per material flow)

Circular inflow is split into two types of inflow: renewable and non-virgin inflow. While renewable materials are one of the two types of circular inflow, we have intentionally excluded them in the rest of this chapter as companies contributing to this guidance do not expect bio-based materials to have a significant impact on the production of electronic products.

For more context refer to the **Circular Electronics System Map**.

Non-virgin inflow

This section exclusively refers to previously used (secondary) materials, components or products, such as recycled materials, second-hand products or refurbished parts. Materials entering the manufacturing facility, not originally part of the product or component should be processed at the material level (e.g., solvents, acids or other chemicals). **Appendix III** provides more information on non-virgin inflow.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- → Weight of the material/component/product
- → Specifications of the material
  - → Virgin (weight or %)
  - → Non-virgin (weight or %)

Example:

Circular inflow at component level: It is possible to use the recycled parts of components to create a new component. For example, Jiva Materials produces recyclable printed circuit boards (PCBs). The semiconductor, Infineon uses these recyclable PCBs from Jiva Materials in its products to minimize electronic waste.[24] This will increase the % non-virgin inflow for Infineon.

2. Include/ exclude

Include

- Total mass of all materials, components or products entering the manufacturing process
- For the most accurate inflow calculations, a company should consider not only the materials that end up in the final product but all input materials, including those that may become operational waste during the manufacturing process such as scraps, leftovers from production or chemicals

Exclude

- Impacts related to the extraction, production and transportation of raw materials before they reach the manufacturing facility
- Data from processes that are not directly related to manufacturing, such as administrative activities or unrelated manufacturing
- Data on the energy consumed during the manufacturing process (use the % renewable energy indicator here)

3. Level of detail of the data

- **Newly produced component or product:** Non-virgin inflow can be evaluated by collecting the mass of each inflow at the material level, as different materials in electronic components or products can have varying degrees of non-virgin content. Obtaining this data for every material present in a component or product can be challenging for a manufacturing company and requires information from upstream suppliers.
- **Secondary materials or components:** Non-virgin inflow can be evaluated at the component or product level if previously used. Consider any material or components added during the preparation for the reuse activities to replace damaged parts, as these additions could be virgin and thus lower the overall percentage of non-virgin inflow.

Example – Newly produced component or product:

A company manufactures a laptop. The weight of all material inflows during the manufacturing process is 2.22 kg; **90%** of all material inflows end up in the final product and **10%** are operational waste. Based on BoM documents from the material suppliers, the following information is available: from the total weight of all material inflows (2.22 kg), **80%** of materials are virgin materials, **20%** of the materials are recycled materials.

The non-virgin inflow for the laptop can be calculated as follows:

- 20% recycled content (material level)
- 80% virgin raw materials (material level)

Total % circular inflow: 20% (20% non-virgin inflow)

4. Recommendations for data collection

Follow these steps to collect data on material specifications (non-virgin inflow) and weight of materials/components. For each of the three different types of manufacturing companies, the data collection is similar, but potentially at a different level of detail.

Newly produced components or products

For the component manufacturing/contracted manufacturing/OEM the actions to obtain insights on the weight and specification of materials used are similar:

- Contact the supplier of either the raw materials, (sub) component or part of the product to obtain insights on the weight and specifications of the materials used in manufacturing as primary data source.
- Contact the OEM on the specifications of materials expected to be used in the manufacturing process of the electronic device and to be included in the procurement specifications.

CTI use case – HP

Among other circularity goals, HP has set a goal to use 30% post-consumer recycled plastic across personal systems and print by 2025. This contributes to the % circular inflow presented in the CTI framework. Goal setting has led HP to seek data insights to inform implementation plans and report performance against the target.
Tracking the use of recycled plastics in devices at HP starts with the raw material used (in this case non-virgin raw materials). The secondary plastics HP uses must be third-party certified to verify they contain a percentage of post-consumer recycled plastic. These raw materials are linked to specific part numbers. HP then calculates the percentage on a bill of materials (BOM) for each product with plastic parts containing certified recycled content, leading to primary data available for the calculation of the % circular inflow.

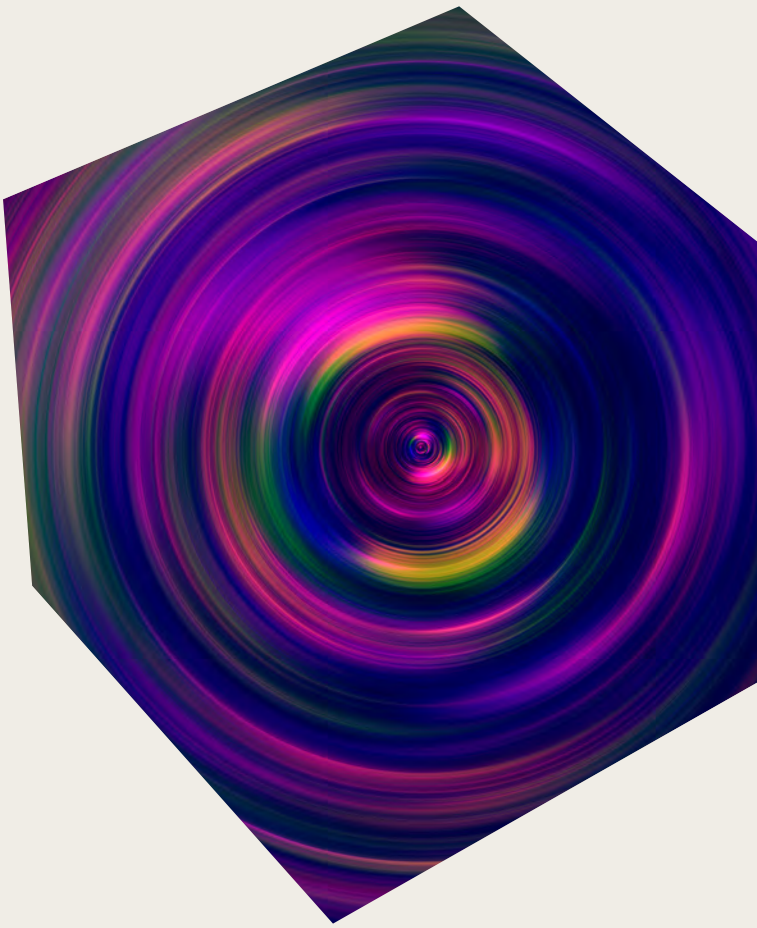
With the detailed information at a product level, HP has an integrated corporate view of the use of post-consumer recycled plastic in its sub-portfolio. The insights generated from the data are crucial in determining plans to continue to drive the company's goals.

Engaging directly with raw material suppliers through the procurement organization is key to having better oversight of the chain of custody. HP uses a common file repository where third-party certificates are uploaded and continuously refreshed when expired to ensure primary data stays available.

By demanding the use of third-party certified plastics, HP is better prepared for upcoming reporting requirements (e.g., CSRD) and ensures the circularity goal status is based on accurate data.

In case access to primary data is challenging:

- Use external databases or research publications on the typical composition of the component or the product;
- If no secondary materials or components are used in the component or product and the component or products has not been used before, the non-virgin content is considered to be 0.



CTI use case – SMX

SMX is a tech company providing industry with a data driven solution to their circularity challenges across the entire value chain of their operations including upstream & downstream partners and customers.

Its solutions "give material memory" and tie this memory to the blockchain while capturing both quantitative and qualitative data on the marked material or component. This is delivered via 1. chemical-based marker, 2. customized XRF reader and 3. blockchain records. Providing it's partners with primary data on % non-virgin inflow of used materials in production.
The technology provides companies with the ability to mark both virgin and recycled materials while demonstrating percentage content of each at component level within the final product in a non-destructive manner.

The solution provides material traceability data from origin, through manufacturing to production, recycling and reuse. A single source of supply chain & material content data tied to the component and/or product throughout its life cycle 1, 2, 3 or more. Potentially providing insights for a calculation of the % non-virgin inflow and % actual recovery.

The company's focuses on supporting all value chain stakeholders such as resources, producers, manufacturers, refurbishers, repairers and recyclers in providing accurate, auditable data on material origin, authenticity and through to repair, sorting for recycling or ultimately reuse. Materials in scope include gold, silver, platinum, copper, nikel, aluminum, steel, lithium, cobalt, natural rubber, organic and synthetic fabrics, plastics and packaging.

Previously used (secondary) materials/components/products

- → Contact the partner executing the preparation for reuse of the component or product and request information on specifications of the materials added.
- → If suppliers cannot provide accurate data, research publications and external databases on average numbers of recovered materials in devices during preparation for reuse activities.
- → If non-virgin materials were added during the preparation for reuse phase, the % non-virgin inflow is considered 100%
- → If new parts were added during the preparation of reuse phase, collect data on their weight and % of non-virgin inflow.

% circular outflow (per material flow)

Circular outflow is determined by multiplying the % recovery potential and % actual recovery of product, components and materials.

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? Appendix III provides more information on the recovery potential.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- → Weight of the material/component/product
- → % of the weight of the material, component, product that is potentially recoverable by design

If a technical material on any level (potentially molecular) can remain at functional equivalent in a next life cycle in a technically feasible and economically viable manner, it is adding to the % recovery potential.

Example:

Imagine a smartphone where various components, such as the display, battery and circuit board, are assembled using adhesive bonding. When this smartphone reaches the end of its technical lifespan, it becomes challenging to separate and recover these components without causing damage. The adhesive makes it difficult to disassemble the device, resulting in a recovery potential close to 0%. Moreover, the glued components are less likely to be reusable or recyclable.

In contrast, consider another smartphone designed with components connected using screws or fasteners. When this smartphone reaches the end of its life, it is relatively easy to disassemble it, allowing for the recovery of individual components like the display, battery and circuit board. The mechanical fastening enables a recovery potential of 100%, as each component can be separated and potentially reused or recycled. The screws used in the assembly may also be designed for reuse or recycling, contributing to a more sustainable end-of-life scenario.

2. Include/ exclude

Include

- Recovery potential of:
  - Materials, e.g., what % of the materials can be recycled
  - Components, e.g., can a component be disassembled and prepared for reuse
  - Products, e.g., what % of the whole product can be disassembled and prepared for reuse
- Recovery potential of operational waste that directly results from the manufacturing process, e.g., recycling potential of excess materials

Exclude

- Data points that do **not directly contribute to assessing the recovery potential** of materials or components or products such as information on unrelated manufacturing processes or administrative activities
- Any impacts related to the extraction, production or transportation of raw materials before they reach the manufacturing facility

3. Level of detail of the data

When selecting the level of detail of the data for assessing the recovery potential of the product, consider the assessment objectives and the type of recovery desired for the electronic device. If aiming to assess a product's **lifetime extension through repair, refurbishment or remanufacturing, assess recovery potential on a product level**.

If the goal of the assessment is the **alternative use of materials recovered through recycling of the electronic devices, it may be more relevant to assess the recovery potential on a material level**. This provides valuable insights into how materials such as copper or plastics can be repurposed for other uses instead of recovering the entire product.

The % recovery potential the product is most often known for the full product (% of the total weight that could be recovered by design) or component level (% of the total weight of a component that could be recovered by design). To ensure accuracy and consistency in calculating the % circular outflow, **calculate the actual recovery on the same data level as the recovery potential**.

Figure 12 illustrates how the % circular outflow assessment can differ depending on whether the company chooses to assess it on a product or material level.

Figure 12: Level of detail of the data

	Potential and actual recovery on product level	Potential and actual recovery on material level
Objective	Increase take-back, recover and resell of laptops to extend the product lifetime	Increase recycling of laptops and reuse or resell of raw materials
Indicators	**% Recovery potential** 70% of the laptop can be disassembled and replaced to be repaired or refurbished **% Actual recovery** 50% of the laptops are being recollected, repaired and refurbished **% Recovery type** 60% of actual recovery is repaired 40% of actual recovery is refurbished	**% Recovery potential** 90% of materials can be recovered through recycling **% Actual recovery** 50% of the laptops are being recollected and recycled **% Recovery type** 100% of actual recovery is recycled
Outcome	**% Circular outflow** **35%** % Recovery potential % Actual recovery The assessment shows strong potential to increase the % outflow by optimizing the recovery potential of laptops, for example, through modular design and increase recollection	**% Circular outflow** **45%** % Recovery potential % Actual recovery The assessment shows strong potential to increase the % outflow by increasing recollection rates

Example:

A company manufactures laptops. The weight of all material inflow during the manufacturing process is 2.22 kg; 90% of all material inputs (2 kg) end up in the final product and 10% (0.22 kg) is operational waste.

Recovery potential for the final product (2 kg):

- 1.2 kg of the components can be disassembled and replace
- 0.8 kg of the components cannot be disassembled in a technically feasible and economically viable way
  - 0.4 kg of these components can be recycled and the remaining
  - 0.4 kg will need to be disposed of

Recovery potential for operational waste (0.22 kg): From the operational waste 0.2 kg can be recycled and 0.02 kg cannot be recovered and need to be disposed of (unrecoverable waste).

To determine the full recovery potential of this laptop, use the following calculation:

- 54% (1.2 kg/2.22 kg) of the final product can be potentially recovered through reuse, repair, refurbishment or remanufacturing of the product (product level)
- 27% (0.4 kg + 0.2 kg/2.22 kg) recovery potential through recycling of replaced materials or components (material or component level)
- 19% (0.4 kg + 0.02 kg/2.22 kg) lost recovery potential due to parts that cannot be recovered in any way and must be disposed of

Total % recovery potential: 81% (54% + 27% potentially recoverable from the final product and operational waste)

4. Recommendations for data collection

An OEM can reach out to up- or downstream suppliers and partners to collect information on the recovery potential. When calculating the recovery potential of a material, component or product, companies may do the following:

- Request a teardown report by external party outlining the portion of materials, (sub-) component or full product that could be recovered by design. Providing insights at component or material level on the recovery potential.
- Use the design principles of the manufacturing company/OEM, outlining the recovery potential of components/material used in the product in scope.
- Request insights on the potential repairability of the components or products at repair, refurbish, remanufacturing companies (or internal departments).

Actual recovery

How much of the outflow does the company recover in practice? 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. Appendix III provides more information on the actual recovery.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- Weight of the material/component/product
- % of the weight of the material, component, product recovered

A manufacturing company will retrieve the number of products, components or materials recovered in any form at the end of life. This includes insights from initiatives such as take-back schemes provided by the manufacturing company and repair services offered by the company itself or in collaboration with partners.

When specific recovery data is not available, the manufacturing company can leverage regional or country-based recovery rates applicable to the relevant product type. Companies may need to use averages or assumptions on the % actual recovery in case product types are not represented in the reporting categories.

Example:

In the conventional model, a company purchases electronic devices such as laptops or tablets. Over time, as these devices require maintenance, upgrades or repairs, the company manages these processes independently, potentially leading to challenges in tracking material use and disposal.

Alternatively, the company could enter a subscription or maintenance contract with an electronic device provider. In this arrangement, the provider retains ownership of the electronic devices. The contract includes provisions for maintenance, repairs and upgrades as needed. By doing so, the provider can effectively manage the outflow and data related to repaired and reused materials. This model enables the company to maintain control over its electronic assets more efficiently, with any refurbished devices seamlessly reintegrated into the company's inventory.

2. Include/exclude

Include

- Actual recovery of:
  - Materials, e.g., what % of the materials are recycled
  - Components, e.g., how many components are recovered and prepared for reuse
  - Products, e.g., what % of the whole product is being disassembled and prepared for reuse
- Actual recovery of operational waste that directly results from the manufacturing process, e.g., what % of excess materials are recycled or recovered otherwise
- Actual recovery of operational waste that directly results from the preparation for reuse, e.g., what % of broken parts that had to be exchanged during repair, remanufacturing or refurbishment were recycled or otherwise recovered

Exclude

- Waste not directly related to the preparation for reuse process, e.g., office waste
- Water consumption and contamination during assembly processes (use % water circularity here)
- Emissions from sources not directly associated with the assembly process itself, such as emissions from employee commuting or unrelated facility activities.

3. Level of detail of the data

To ensure accuracy and consistency in calculating the % circular outflow, it's crucial to **determine the actual recovery on the same data level as the recovery potential was determined.** For example, if recovery potential was determined on product level then the actual recovery should also be assessed on product level.

When calculating the actual recovery, collect data on the mass of the material, part or product actually recovered compared to the overall mass of the material, component or product.

The level of detail of the data depends on the type of recovery the company aims for.

Repair: Takes place at either component or full product level. Request data on the weight of the repaired component or product

Refurbishing: Takes place at component or full product level (e.g., replacement of screens, tiles). Request data on the weight of the component or product placed onto market after the refurbishing process.

Remanufacturing: Takes place at component level (e.g., replacement of the PCB). Request data on the weight of the component or product placed onto market after the remanufacturing process.

Recycling: Takes place at material, component or full product level (e.g., aluminum is recovered through recycling). Request data on the weight of the materials ending up in recycling.

Example:

Suppose a company manufactures a laptop. The weight of all material inputs during the manufacturing process is 2.22 kg; 90% of all material inputs (2 kg) end up in the final product and 10% (0.22 kg) are operational waste.

Actual recovery for the final product (2 kg):

- → 1.2 kg of the parts are disassembled and reused;
- → 0.1 kg out of potentially 0.4 kg is actually recycled;
- → 0.7 kg is disposed of.

Actual recovery for operational waste (0.22 kg):

- → 0.1 kg is actually recycled.
- → 0.12 kg is not recovered and disposed of.

To determine the full actual recovery of this laptop, use the following calculation:

- → 54% (1.2 kg/2.22 kg) of the final product can be potentially recovered through reuse, repair, refurbishment or remanufacturing of the product (product level)
- → 9%% (0.1 kg + 0.1 kg/2.22 kg) actual recovery through recycling of replaced materials or components (material or component level).
- → 37% (0.7 kg + 0.12 kg/2.22 kg) parts that could not be recovered in any way and must be disposed of.

Total % actual recovery: 63% (54% + 9% actually recovered from the final product and operational waste)

%circular outflow: 51% (% recovery potential (81%) * % actual recovery (63%))

4. Recommendations for data collection

Begin the **assessment of various outflow streams**, such as the products, components, waste, **separately**. This approach allows for a more thorough analysis of potential areas for improvement. Below are recommendations outlined to cover potential data gaps.

To calculate the actual recovery rate of a material, component or product, a comprehensive examination across the entire value chain is necessary to determine if any form of recovery occurs.

- → Request data on number of devices returned by take-back scheme facilitated by the component manufacturing, contracted manufacturing or OEM manufacturing and assembly company
- → Acquire data on recycling programs conducted by recycling partners to recover specific materials, components or products.
- → Collect information on materials, components or products repaired, refurbished or remanufactured during their life cycle by the repair, refurbishing or remanufacturing partners
- → Collect information on the number of devices returned at distribution and retail companies for repair, refurbishing, remanufacturing

Additionally, more general reports and standards could be used for standard actual recovery rates:

- → Generic data on regional/national recovery rates for electronic devices (e.g., based on WEEE product type categorization).
- → Academic research on recovery rates for electronic devices for specific product categories/regions.
- → Extended Producer Responsibility (EPR) schemes in different geographies.

Excursus: extended producer responsibility (EPR):

Extended producer responsibility (EPR) is an environmental policy approach that shifts the responsibility of a product's life cycle to the producer, including design, take-back, recycling and final disposal. Variations of EPR now have a worldwide presence with an initially strong focus on reducing packaging waste (polluter-pays-principle).

The European Union requires producers to follow certain rules, including registering as a producer, meeting design and labelling requirements, reporting on the amount of product or packaging sold, achieving recycling targets and funding recycling and recovery at the end of life. The rules apply to all products, but there are three main categories that have more waste and toxins: packaging, electrical and electronic equipment and batteries.[25]

Two important reflection points on data collection:

1. Time gap between placing product onto market and recovery of the product

Electronic devices stay in use on average for 4.5 years,[26] which means the actual recovery of a product that has just been introduced onto the market cannot be reflected.

In this case, companies may:

- Use actual recovery data for the previous type of the product of assessment and use the recovered weight-and total weight placed on market for the assessment.
- Use proxy data for similar products (based on country/continental average) for the products that are not part of an own take-back scheme.

2. The actual recovery of components

Recovery at component level does not often take place: e.g., repair rates of device are tracked at the product level and recycling rates in many cases at the product or material level. One way to assess the recovery of a component is to use the weight of the component in scope and divide this weight by the weight of the product in which the component is used (weight component/weight device). Multiply this weight by the actual recovery rate (% actual recovery) of the product in scope to obtain insights into the actual recovery of the component.

An important note: The use of these generic data sources is based on assumptions. For example: only the recovery rates of washing machines are known for a specific geography, not the brand or type, let alone the components. We advise the company to track and document assumptions made for future reference and comparability.

2 ***Optimize the Loop***

→ To calculate: % critical material inflow and % recovery type

% critical material inflow

Critical materials are materials prone to becoming scarce in the relatively near future and are difficult to substitute without hampering functionality. Several institutions have identified critical raw materials. The EU, for example, identified 34 raw materials in 2023.[27] **Refer to existing definitions and classifications or critical materials**, such as those developed by the European Union or the United States. These definitions typically consider factors such as the economic importance of the material, the risks associated with its supply and its importance to emerging technologies. Appendix III provides more information on critical (raw) material inflow.

1. Data points required

For material, component, product, business unit and company level the company needs to have the following data points:

- Weight of the critical material in the component or product in scope
- Weight of the material/component/product in scope

2. Include/exclude

Include

- All critical materials present in the components or products in scope of the assessment

Exclude

- Critical materials that are not directly related to the component or products in scope of the assessment

3. Level of detail of the data

To calculate the critical material, the total weight of inflow and the weight of critical raw material needs to be known. This can only be done at a material level.

4. Recommendations for data collection

Companies could take the actions below to collect data on critical raw materials for the three different manufacturing companies:

- Contact the supplier of either the raw materials, (sub) component or part of the product to obtain insights on the weight and specifications of the critical raw materials used in manufacturing as primary data source. In case other parties are involved in the procurement process responsible for the delivery of the critical raw materials, contact these parties.
- Contact the internal departments (e.g., R&D/design/product development) on the raw materials expected to be used in the manufacturing process of the electronic devices.
- Perform a teardown of the device in scope or request a teardown report at the manufacturer to gain insights into the use of critical raw materials.

If a manufacturing company is not able to collect direct information on critical materials contained in the component or product from its suppliers, it is possible to use benchmark data on typical material compositions in components or products. Look for **component/product-specific material compositions** to make most accurate assumptions, including specific research performed on the materials contained in components by taking the components apart.

Recovery type

For the Optimize the Loop module, the % recovery type provides a deep exploration of higher value retention strategies within company reach. % recovery type is applied to % actual recovery. Appendix III provides more information on the recovery type.

1. Data points required

The material level requires the following information:

- The weight or percentage of recycled materials actually recovered **per type of recovery**
- The weight of percentage of operational waste or residues actually recovered **per type of recovery**

2. Include/exclude

Include

- Recovery of recycled materials or components or products processed in the recycling facility and used for another product
- Recovery of operational waste that directly results from the recovery of the component or product, e.g., residues or non-recyclable material parts

Exclude

- Recovery of materials not directly related to the recycling process, e.g., office waste

3. Level of detail of the data

To determine the recovery % per type, assess the performance of each type of recovery at product or component level due to the availability of data at component or product.

4. Recommendations for data collection

To determine the recovery % per type, assess the performance of the recovery per type of each material, component or product. Engage with downstream partners: companies offering repair or refurbishing services, recyclers or waste handlers on insights into recovery of devices.

The manufacturing company can take the following steps to obtain the data:

- Request a detailed breakdown of materials, components or products that undergo repair, refurbishing, remanufacturing or recycling either internally or at external partner.
- Research data sources on recycling initiatives at the component level, including the types of components recycled and their corresponding recovery rates.
- Search for detailed reports on refurbishing or remanufacturing processes, especially on the types and numbers of components refurbished or remanufactured for the product in scope.

CTI use case – Philips

Philips is a health technology company. Its purpose is to improve the health and well-being of 2.5 billion people annually by 2030. It has operationalized its purpose by adopting a fully integrated approach to doing business responsibly and sustainably. Its circularity ambition is to help customers "do more with less" by applying its circularity principles "use less, use longer and use again" in five strategic areas, from design to end-of-use management. Philips has committed to delivering on voluntary circularity targets by 2025 as part of its environmental, social and governance (ESG) commitments, which includes generating 25% circular revenues. Circular revenue is an overarching metric that collates practices at Philips related to products, services and solutions that contribute to circularity. It measures the revenue contributions from design to responsible end-of-use management.

One important way to look at the impact of circularity metrics is to look at material flows at both the organizational and product levels, similar to CTI. Philips performed a CTI assessment on one of its medical products.

It used multiple data sources on inflow, potential and actual recovery to calculate the % circularity for a new and refurbished medical product:

- **Inflow:** The company derived the main source by using the data on renewable, reused and recycled content from the bill of materials (BoM). The BoM contains the material composition and weight of the assessed product and is stored in the Philips Environmental Profit and Loss Account. Using the BOM is best practice due to the use of a complete inventory of materials used in the production.
- **Circular outflow:** It used WEEE recycling rates to determine the circular outflow.
- **Recovery potential**: Expert input helped determine recovery potential of the devices in scope.
- **Actual recovery:** The company calculated the actual recovery based on the circular outflow and recovery potential.

The assessment revealed that the material circularity for a refurbished product is 40% higher compared to a new product. This highlights the positive impact on the % material circularity of the refurbishment program and the importance in the overall circular strategy.

Actual lifetime

A product's lifetime is 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. 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".[28]

1. Data points required

- Component or product actual lifetime in years
- Average component or product actual lifetime in years

1. Include/exclude

Include

- Actual lifetime of component or product in scope of the assessment

Exclude

- Actual lifetime of component or product not directly related to the component manufacturing company

2. Level of detail of the data

Assess the actual lifetime of electronic devices on a product or component level instead of a material level because the lifetime of a product or component is dependent on various factors, including its design, construction and use patterns.

By assessing the actual lifetime of products or components, a manufacturing company can obtain a more accurate assessment of the product or component's durability and identify areas for improvement in their design and recovery processes. Additionally, assessing the actual lifetime can help a manufacturing company to identify opportunities for repair, refurbishing or remanufacturing, which can extend the lifespan and reduce the need for frequent upgrades and replacements.

3. Recommendations for data collection

Calculating the actual lifetime can be challenging for a manufacturing company as it requires data from up- and downstream suppliers:

The **product actual lifetime** can be obtained by collecting data on the lifespan of individual product or components, either through information from retailers, other manufacturing companies, customer surveys or through data collected from repair or refurbishing services. This data can provide insights into how long individual products or components are being used before becoming obsolete or requiring replacement.

The **average product actual lifetime** can be obtained by analyzing data on the lifespan of a larger sample of product or components, either from the company's own sales data or from industry-wide data. This data can provide insights into the typical lifespan of components and can be used as a benchmark for comparison with the company's own products or components. The following data sources could be used:

Product actual lifetime

- Contact component manufacturer/OEM to gain insights into the lifespan of the components or product
- Contact retailers or distributors to gain specific insights into the lifespan of individual components based on end-user feedback and warranty claims
- Reach out to repair or refurbishment services about the components'/products' repairs and replacements
- Conduct individual customer surveys on how long specific components/products lasted before replacement or repair

Average product lifetime

- Collaborate with manufacturing companies producing similar components/products to gather industry-wide data on the typical lifespan
- Analyze own sales and returns data to determine the typical lifespan before components/products require replacement
- Conduct wider customer surveys or feedback forms on the lifespan of products in various environments and use patterns
- Conduct individual customer surveys on how long specific products lasted before needing replacement or repair

Value chain activity 3: Distribution and retail

Distribution and retail

Distribution and retail companies sell and distribute electronic products to B2C or B2B customers. These companies do not produce themselves but work with manufacturers and suppliers to source a wide range of electronic products, including smartphones, laptops, smart home devices and other electronic products. They may operate physical retail stores, online stores or both. These companies may also offer financing options, trade-in programs to customers.

Step 1 - Scope

The answers to key questions explained in the first part of this document define the scope of the assessment: **Part 1 – General CTI explanation.**

Step 2 - Select

CTI offers a menu of indicators that enable the company to answer the questions from the scoping step. The tables below offer guidance on selecting indicators for specific activities based on their materiality and usefulness in providing insights, considering the unique business context of each activity.

We make the following distinctions between the different indicators:

- **Required:** Include the indicator as part of the % material circularity (Close the Loop);
- **Recommended:** We recommend the inclusion of the indicator in the assessment, since the assessment provides relevant insights for the activity in scope;
- **Optional:** The indicator is optional; companies can decide to include it based on their sustainability and business objectives.

Appendix II – Distribution and retail provides an explanation of the indicators and the reasoning behind their classification as required, recommended or optional.

Table 14: Suggested indicators for Distribution and retail

Close the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% material circularity	Required	Required	Required
% water circularity	Optional	Optional/recommended	Optional
% renewable energy	Recommended	Recommended	Recommended
Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% critical material	Recommended	Recommended	Optional
% recovery type	Recommended	Recommended	Recommended
On-site water circulation	Optional	Optional	Optional
Actual lifetime	Recommended	Recommended	Recommended
Value the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Circular material productivity	Not recommended	Not recommended	Not recommended
CTI revenue	Recommended	Recommended	Recommended
Impact of the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
GHG impact	Recommended	Recommended	Recommended
Nature impact	Optional	Optional	Optional

Step 3 — Collect

Step 3 explains how perform data collection for: % material circularity, % critical materials, % recovery type and actual lifetime.

To perform a CTI assessment, retailers of electronic devices can **gather primary data from various up- and downstream value chain partners**. Collecting primary data ensures high accuracy and reliability in the assessment. If primary data is unavailable, retailers can rely on secondary sources like external databases or publications.

Depending on the company's position in the value Figure 13 shows potential sources of primary data, including manufacturing for inflow data and preparation for reuse and recyclers for outflow data.

Calculating the selected indicators requires multiple data points. A company must **carefully consider which data to include or exclude** and the level of granularity.

Figure 13: Potential sources of primary data

	Upstream		Own Operations	Downstream		
Flow	Inflow	Data Flow →	Company boundary	← Data Flow	Outflow	
Activity	**Component, contracted and OEM manufacturing**	**Preparation for reuse services**	**Distribution and retail**	**Use**	**Preparation for reuse services**	**Recycling**
Potential data points	→ Product/component quantities → Product/component weight → Material specifications → Critical materials → Recovery potential → Waste	→ Product/component weight → Product/component specifications → Recovery potential	→ Product/component quantities → Product/component weight → Actual recovery	→ Actual lifetime → Actual recovery	→ Product/ component weight → Recovery potential → Actual recovery	→ Material weight → Critical materials → Actual recovery
Datal point level	Product or component level	Product or component level	Product level	Product level	Product or component level	Material level
Potential data sources	→ Procurement and sales data → Material safety data sheets (MSDS) → Bill of Materials (BOM) → Disassembly or repair reports → Waste reports	→ Material safety data sheets (MSDS) → Bill of Materials (BOM) → Disassembly or repair reports → Waste reports	→ Procurement and sales data → EoL service providers → Waste handler reports	→ Customer surveys	→ Disassembly or repair reports → Waste reports	→ Recycling reports → Material tracking sheets → Certificates → Laboratory and testing reports → Waste reports

1 ***Close the Loop***

→ To calculate: % material circularity

% circular inflow (per material flow)

Circular inflow is split into two types of inflow: renewable and non-virgin inflow. While renewable materials are one of the two types of circular inflow, we have intentionally excluded them in the rest of this chapter as companies contributing to this guidance do not expect bio-based materials to have a significant impact on the production of electronic products.

Non-virgin inflow

This section exclusively refers to previously used (secondary) materials, components or products. Appendix III provides more information on non-virgin inflow.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- Weight of the material/component/product in scope of the assessment
- Material, component or product specifications:
  - Virgin (weight or %)
  - Non-virgin (weight or %)

Examples:

- **Circular inflow at material level:** For example, mobile phone manufacturer Fairphone uses 100% recycled tin in the solder of Fairphone 4 and over 50% of the plastic is post-consumer recycled.[29] This increases the % non-virgin inflow for a Fairphone.
- **Circular inflow at the product level:** Another example is selling reused electronic devices such as laptops or phones. Such second-hand devices are considered 100% non-virgin inflow if no materials or parts have been added during the prepare for reuse phase, e.g., repair or refurbishment.

2. Include/exclude

Include

- Information on the types, composition, quantities and weight of materials, components or products sold to customers and in scope of the assessment
- Impacts related to the extraction and production of products that enter the retail company
- Information on the types, composition, quantities and weight of materials or components that have been added to a second-hand device during the prepare for reuse phase because damaged parts needed to be replaced, e.g., broken screens or batteries

Exclude

- Data from processes that are not directly related to the retail of a product, such as administrative activities or unrelated manufacturing processes
- Data on the energy consumed during the production process (use the % renewable energy indicator here)

3. Level of detail of the data

Newly produced devices: The most precise measurement of non-virgin inflow can be achieved by collecting the mass of each inflow at the material level, as different materials in electronic devices can have varying degrees of non-virgin content. Obtaining this data for every material present in an electronic device can be challenging for a retailer, since devices will enter the company boundaries as a full product and requires information from upstream suppliers such as manufacturers or OEMs.

Secondary materials or components: The non-virgin inflow can be evaluated at the product level if the product has been previously used and is being resold through a retailer. Consider any materials or components that may have been added during the preparation for reuse phase to replace damaged parts, as these additions could be virgin and thus lower the overall percentage of non-virgin inflow.

Example for a newly produced device:

A company sells a laptop. Based on BoM documents from the OEM, the following information is available: 80% of materials are virgin materials, 20% of materials are recycled materials.

The non-virgin inflow for the laptop can be calculated as follows:

- 20% recycled content
- 80% virgin raw materials (material level)

Total % circular inflow: 20% non-virgin inflow.

4. Recommendations for data collection

To begin collecting data on non-virgin inflow, a retail company can follow these steps:

For previously used materials/components/products

- Contact the suppliers or partners responsible for the preparation for reuse (e.g., repair) of the electronic device and request information on the material specifications of the materials or components added during the repair, refurbish, remanufacturing activities.

For the distribution and retail company, the following actions could be taken for data collection if the engagement with the manufacturers doesn't lead to the required data points:

- If the supplier cannot provide accurate data, research on the typical preparation of reuse process of the device and the parts replaced during these activities, can be conducted using external databases or research publications.
- If there were no virgin materials or components added during the preparation for reuse phase, the % non-virgin inflow is considered 100%. The entire device is considered second-hand and therefore 100% non-virgin.
- If parts made from virgin materials such as batteries or screens were added during the preparation for reuse phase, collect data on their weight and include as virgin materials.

For newly produced devices

- Contact the suppliers of electronic devices and request information on the weight and material specifications (e.g., based on the BOM or BOD) of the product at the material level.

For the distribution and retail company, the following actions could be taken for data collection if the engagement with the manufacturers doesn't lead to the required data points:

- If the supplier cannot provide accurate data, research on the typical material composition of the product can be conducted using external databases or research publications.
- If there are no secondary materials or components present in the product and the product has not been used before, the non-virgin content is considered to be 0.

% circular outflow (per material flow)

Circular outflow is determined by multiplying the % recovery potential and % actual recovery of product, components and materials.

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.)? Appendix II provides more information on the recovery potential.

1. Data points required

For material, component, product, business unit and company level, the following information is needed:

- Weight of the material/component/product
- % of the weight of the material, component, product that is potentially recoverable by design.

If a technical material on any level (potentially molecular) can remain at functional equivalent in a next life cycle in a technically feasible and economically viable manner, it adds to the % recovery potential.

2. Include/exclude

Include

Recovery potential of:

- → Materials, e.g., what % of the materials can be recycled
- → Components, e.g., can a component be disassembled and prepared for reuse
- → Products, e.g., what % of the whole product can be disassembled and prepared for reuse

Exclude

- → Data points that do **not directly contribute to assessing the recovery potential** of materials, components or products in scope, such as information on unrelated manufacturing processes or administrative activities3. Level of detail of the data

3. Level of detail of the data

When selecting the level of detail of the data for assessing the recovery potential of the product under scope, consider the assessment objectives and the desired type of recovery for the electronic device. If the aim is to extend the lifetime of the product through repair, refurbishment or remanufacturing, assess the recovery potential on a product level. This provides valuable insights into the overall recoverability of the product and identifies areas where recovery potential can be enhanced.

If the aim is to **assess the alternative use of materials recovered through recycling from electronic devices, it may be more relevant to assess the recovery potential on a material level**. This provides valuable insights into how materials such as copper or plastics can be repurposed for other uses instead of recovering and repurposing the entire product.

The % recovery potential of the product is most often known for the full product (% of the total weight that could be recovered by design) or component level (% of the total weight of a component that could be recovered by design). To ensure accuracy and consistency in calculating the % circular outflow, **calculate the actual recovery on the same data level as the recovery potential**, whether it is assessed on a material or product level.

Figure 14 illustrates how the % circular outflow assessment can differ depending on whether the company chooses to assess it on a product or material level.

Figure 14: Level of detail of the data

	Potential and actual recovery on product level	Potential and actual recovery on material level
Objective	Increase take-back, recover and resell of laptops to extend the product lifetime	Increase recycling of laptops and reuse or resell of raw materials
Indicators	**% Recovery potential** 70% of the laptop can be disassembled and replaced to be repaired or refurbished **% Actual recovery** 50% of the laptops are being recollected, repaired and refurbished **% Recovery type** 60% of actual recovery is repaired 40% of actual recovery is refurbished	**% Recovery potential** 90% of materials can be recovered through recycling **% Actual recovery** 50% of the laptops are being recollected and recycled **% Recovery type** 100% of actual recovery is recycled
Outcome	**% Circular outflow** **35%** % Recovery potential % Actual recovery → The assessment shows strong potential to increase the % outflow by optimizing the recovery potential of laptops, for example, through modular design and increase recollection	**% Circular outflow** **45%** % Recovery potential % Actual recovery → The assessment shows strong potential to increase the % outflow by increasing recollection rates

Example:

A company sells a laptop. Based on a disassembly report from the manufacturer, the retailer gets the following information:

- From the final product 80% of the parts can be disassembled and recovered, while 20% of the parts cannot be disassembled in a technically feasible and economically viable way;
- 10% of these components can potentially be recycled and the remaining 10% will need to be disposed of as they are not suitable for recycling or other recovery.

To determine the recovery potential of this laptop, use the following calculation:

- 80% of the final product is potentially recoverable through reuse, repair, refurbishment or remanufacturing of the product (product level);
- 10% of the remaining parts is recyclable (material or component level);
- 10% lost recovery potential due to parts that are not recoverable in any way and must be disposed of.

Total % recovery potential: 90% (80% + 10% potentially recoverable through reuse or recycling)

4. Recommendations for data collection

Defining the recovery potential of an electronic device can be challenging for a retailer as most of the information needed, such as for teardown reports or design principles, lie with the product manufacturer. A retailer can reach out to up- or downstream suppliers and partners to collect information on the recovery potential. This includes:

- Request a product teardown report at OEM outlining the portion of the product that can potentially be recovered
- Request the potential repairability of the products at repair companies, potential refurbishing or remanufacturing of the (or a portion of the weight of the) products/components/materials at partners
- Review design principles of the manufacturer on the used design for repairability/future recovery of the device in scope.

Actual recovery

How much of the outflow does the company recover in practice? 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. Appendix II provides more information on the actual recovery.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- % of the weight of the material, component, product actually recovered.
- Which could be determined by dividing the: weight of the material, component, products recovered/total weight of material, component, products in scope).

Retailers can play a significant role in promoting the recovery of electronic devices by establishing collection and take-back programs for products that can be prepared for reuse or recycled. Due to their closer relationships with B2C or B2B end-customers compared to players further upstream in the electronic value chain, retailers can leverage these relationships to support the take-back of electronic devices. By doing so, retailers can encourage customers to return their devices, which can help reduce waste and promote resource efficiency.

2. Include/exclude

Include

- Actual recovery of:
  - Materials, e.g., what % of the materials are recycled
  - Components, e.g., how many components are recovered and prepared for reuse
  - Products, e.g., what % of the whole product is being disassembled and prepared for reuse
- Actual recovery of operational waste that directly results from the preparation for reuse, e.g., what % of broken parts that had to be exchanged during repair, remanufacturing or refurbishment were recycled or recovered otherwise afterwards.

Exclude

- Waste not directly related to the retail of devices, e.g., office waste
- Water consumption and contamination related to retail operations (use % water circularity here). Emissions from sources not directly associated with retail operations itself, such as emissions from employee commuting or unrelated facility activities

3. Level of detail of the data

To ensure accuracy and consistency in calculating the % circular outflow, companies should **determine the actual recovery on the same data level as the recovery potential**. For example, if the company determined the recovery potential on a product level, then it should also assess the actual recovery on a product level.

When calculating the actual recovery, collect data on the mass of the material, part or product actually recovered compared to the overall mass of the material, component or product.

The level of detail of the data is dependent on the type of recovery the company aims for.

- **Repair:** Takes place at either component or full product level. Request data on the weight of the repaired component or product.
- **Refurbishing:** Takes place at component or full product level (e.g., replacement of screens, tiles). Request data on the weight of the component or product placed onto market after the refurbishing process.
- **Remanufacturing:** Takes place at component level (e.g., replacement of the PCB). Request data on the weight of the component or product placed onto market after the remanufacturing process.
- **Recycling:** Takes place at material, component or full product level (e.g., aluminum recovered through recycling). Request data on the weight of the materials ending up in recycling.

Example:

A company sells a laptop. Based on a repair report from the partner taking care of the preparation for reuse activities, the retailer receives the following information:

From the final product on average 75% of the parts are disassembled and recovered. From the 25% of the parts that cannot be disassembled in a technically feasible and economically viable manner, 5% of the materials are recycled and the remaining 20% are considered operational waste and disposed of.

To determine the actual recovery of this laptop, use the following calculation:

- 75% of the final product is recovered through reuse, repair, refurbishment or remanufacturing of the product (product level)
- 5% of the remaining parts is recycled (material or component level)
- 20% of parts are disposed of as they are not recovered in any way

Total % actual recovery: 80% (75% + 5% recovery through reuse or recycling)

% circular outflow: 72% (% recovery potential (90%) * % actual recovery (80%)

4. Recommendations for data collection

Begin the **assessment of various outflow streams**, such as the electronic devices and waste, **separately**. This approach allows for a more thorough analysis of potential areas for improvement and optimization of the circular outflow. Regulations, such as the CSRD, may require differentiation between waste and material outflows.

When calculating the actual recovery for a material, component or product, various methods are available for the distribution and retail company to obtain data:

- → Request internal data on the number of devices taken back based on take-back schemes, swap and trade mechanisms and devices brought back by customers.
- → Review partner data on the number of devices returned for preparation for reuse activities at partners by customers buying the device at the distribution and retail company.
- → Acquire data on recycling programs conducted by recycling partners to recover specific materials, components or products.

More general reports and standards may be used to gain insights into assessment of recovery potential of proxy electronic devices, such as:

- → Generic data on regional/national recovery rates for electronic devices (e.g., based on WEEE product type categorization). Determine the market share of the products placed on market by the company in scope and determine based on the market share of the company the number of products recovered on an annual basis (only applicable when the absolute numbers of recovered products are known).

Important reflection points on data collection:

Time gap between placing product on the market and recovery of the product.

Electronic devices stay in use on average for 4.5 years,[30] which means it is not possible to reflect the actual recovery of a product that has just been introduced on the market. In that case, companies may use:

- → Actual recovery data for the previous type of the product of assessment and use the recovered weight and total weight placed on the market for the assessment;
- → Proxy data for similar products (based on country/continental average) for the products that are not part of a company's own take-back scheme, etc.[31, 32]

CTI use case – Dustin

Dustin is a Swedish information technology (IT) company that primarily operates as a reseller of IT products and services. Founded in 1984, Dustin has grown to become one of the leading suppliers of IT solutions to businesses and organizations in the Nordic region. Since 2020, it also operates in Belgium, and the Netherlands. The company offers a wide range of products, including computers, servers, networking equipment, software and services such as consulting, implementation and support.
In recent years, Dustin Group has increasingly emphasized its commitment to sustainability, including circularity. Circular economy principles involve minimizing waste and making the most out of resources by reusing, recycling and refurbishing products rather than disposing of them after their initial use. Dustin has recognized the importance of integrating circularity into its business model to reduce environmental impacts and contribute to a more sustainable future.

Dustin embraces a closed-loop vision and future in which e-waste is minimized through the use of durable products that undergo continuous cycles of reuse and recycling. Dustin has introduced a take-back program aimed at contributing to its vision. This program offers customers and stakeholders the opportunity to return their electronic products and devices for refurbishment, recycling or responsible disposal. This scheme aligns with the % actual recovery in CTI.

The company measures the program's success through key performance indicators such as reuse and recycling rates. Currently, "take-back" refers to the process of reclaiming a proportion of products, specifically laptops, monitors, telephones and desktop PCs, that the company has previously sold or distributed. These products are generally at the end of their life cycle, obsolete or no longer required by the customers.

Internal and external parties provide data on take-back through a PowerBI platform, providing a comprehensive overview of product take-back schemes to steer take-back metrics, such as the revenues classified as circular compared to the total sales.

To take back the devices, the company delivers safe boxes for customers to send their old IT equipment back to Dustin centers for processing. Two types of processes are currently in place:

- Dustin reuses products (for which the customer receives compensation and an environmental savings report);
- The company recycles other products responsibly

This process provides the company with the opportunity to track and report the total number of devices taken back annually and is a primary data source for the % actual recovery.

2 ***Optimize the Loop***

→ To calculate: % critical material inflow and % recovery type

% critical material inflow

Critical materials are materials prone to becoming scarce in the relatively near future and are difficult to substitute without hampering functionality. Several institutions have identified critical raw materials. The EU, for example, identified 34 raw materials in 2023.[33] **Refer to existing definitions and classifications or critical materials**, such as those developed by the European Union or the United States. These definitions typically consider factors such as the economic importance of the material, the risks associated with its supply and its importance to emerging technologies. Appendix III provides more information on critical (raw) material inflow.

1. Data points required

For material, component, product, business unit and company level the company needs to have the following data points:

- Weight of the critical material in the component or product in scope
- Weight of the material/component/product in scope

2. Include/exclude

Include

- All critical materials present in the components or products in scope of the assessment

Exclude

- Critical materials that are not directly related to the component or products in scope of the assessment

3. Level of detail of the data

Collect data for the critical material inflow indicator at the material level. By analyzing critical materials at the material level, it is easier to identify risks and opportunities to support the recirculation of scarce materials and improve the circularity of critical materials.

4. Recommendations for data collection

Companies can take the following actions to collect data:

- Contact the supplier of either the raw materials, (sub) component or part of the product to obtain insights on the weight and specifications of the critical raw materials used;
- Contact the internal departments (e.g., R&D/design/product development) on the critical raw materials expected to be used in the manufacturing process of the electronic devices.

If a retailer is not able to collect direct information on critical materials contained in the electronic devices from its suppliers, it is possible to use benchmark data on typical material compositions in electronic devices. Look for **device-specific material compositions** to make most accurate assumptions.

Example:

A company can use a variety of proxy or benchmark data for specific electronic devices by using external research through online resources such as:

- Visualizing the Critical Metals in a Smartphone
- Metallic resources in smartphones
- Raw materials in a laptop
- Recycled material criticality for laptops
- Raw Materials in the Battery Value Chain
- Critical Raw Materials for Strategic Technologies and Sectors in the EU
- The semiconductor and critical raw material ecosystem at a time of great power rivalry

% recovery type

For the Optimize the Loop module, the % recovery type provides a deep exploration of higher value retention strategies within company reach. % recovery type is applied to % actual recovery. Appendix II provides more information on the recovery type.

Analyzing the recovery types of electronic devices can provide retail companies with valuable **insights into whether their products are being recirculated and retained at the highest possible value**. By identifying the recovery types of their products, retailers can also **identify potential areas for improvement** in their product design and recovery processes. This approach can help retailers to optimize their circular economy performance, reduce waste and promote resource efficiency.

1. Data points required

The material, component, product, business unit or company levels require the following information:

- The weight or percentage of material, component or product actually recovered **per type of recovery**
- The weight or percentage of waste that directly results from the preparation for reuse process for secondary devices actually recovered **per type of recovery**

2. Include/exclude

Include

- Recovery of material, components or products in scope of the assessment
- Waste that directly results from the preparation for reuse process for secondary devices, e.g., replacement broken parts during repair services

Exclude

- Recovery of materials not directly related to the recycling process, e.g., office waste 3. Level of detail of the data

3. Level of detail of the data

Assess the recovery type for devices at product level because the recovery type is often dependent on the condition and the design for higher value recovery.

Assessing the recovery type at the material level can be misleading because it does not consider the condition of the device or the suitability of its design for different recovery methods. **By assessing the recovery type at the product level, retailers can obtain a more accurate assessment for identifying areas for improving their actual recovery through adjustments in their recovery processes.**

4. Recommendations for data collection

To determine the recovery % per type, assess the performance of the recovery per type for each material, component or product. Categorize the recovery types based on the specific processes implemented (reuse, repair, remanufacturing/refurbishing, recycling). **Engage with downstream partners such as companies offering repair or refurbishing services, recyclers or waste handlers. This allows for a better understanding of how these materials are reprocessed or reused.**

To evaluate the recovery type, a retailer can consider the following data points:

- Build a database presenting a detailed breakdown of products taken back to the retailer that undergo repair, refurbish, remanufacturing activities;
- Research information on the refurbishing or remanufacturing processes, particularly the specific materials, components or products involved and their overall recovery percentages during these activities;
- Develop customer surveys to gain insights into the lifetime extending or end of life practices customers use most often per product type (potentially aligned with WEEE product categories).

Actual lifetime

A product's lifetime is defined 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. 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".[34] Appendix II provides more information on the actual lifetime.

1. Data points required

→ Product actual lifetime in years

→ Average product actual lifetime in years

2. Include/exclude

Include

→ Actual lifetime of electronic devices in scope of the assessment

Exclude

→ Average lifetime of electronic devices not directly related to the product category

3. Level of detail of the data

Assess the actual lifetime of electronic devices on a product level instead of a material level because the lifetime of a product is dependent on various factors, including its design, construction and use patterns. Assessing the lifetime of a product at the material level can be misleading because it does not consider these factors.

By assessing the actual lifetime of electronic devices at the product level, retailers can obtain a more accurate assessment of the product's durability and identify areas for improvement in their product design and recovery processes. Additionally, assessing the actual lifetime of electronic devices at the product level can help retailers identify opportunities for repair, refurbishing or remanufacturing, which can extend the product's lifespan and reduce the need for frequent upgrades and replacements.

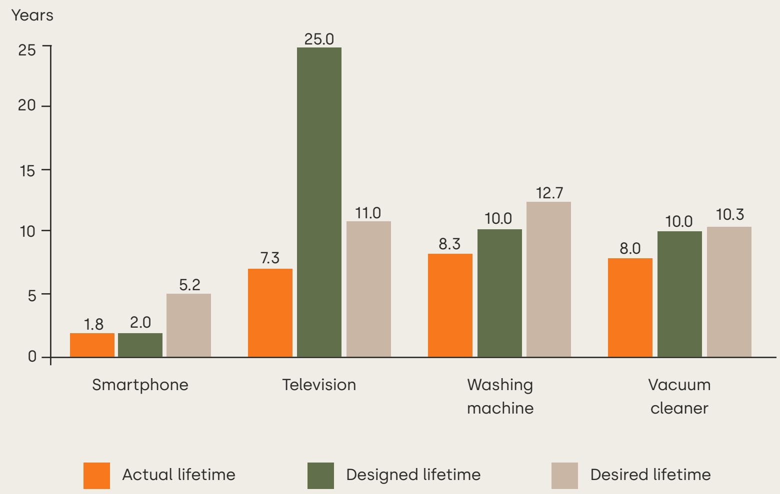
4. Recommendations for data collection

Collecting the required data to calculate the actual lifetime can be challenging for a retail company as it requires data from up- and downstream suppliers. The role of the retailer in the value chain provides a large opportunity to collect data on the product actual lifetime and average product actual lifetime due to the large number of products sold, brought back for repairs and handled for end of life processes.

The **product actual lifetime** can be obtained by collecting data on the lifespan of individual devices, either through information from OEMs, product brands, customer surveys or through data collected from repair or refurbishing services. This data can provide insights into how long individual devices are being used before becoming obsolete or requiring replacement.

The **average product actual lifetime** can be obtained by analyzing data on the lifespan of a larger sample of devices, either from the company's own sales data or from industry-wide data. This data can provide insights into the typical lifespan of electronic devices and can be used as a benchmark for comparison with the company's own products.

Figure 15: Lifetimes for smartphones, televisions, washing machines and vacuum cleaners



Adapted from European Environment Agency: Europe's consumption in a circular economy: benefits of longer lasting electronics

Value chain activity 4: Use

Use

Companies (or individuals) use electronic devices in their operations, such as laptops/phones, as well as higher value equipment. They do not produce the devices themselves but can work in collaboration with OEMs, retailers or leasing companies to use electronic devices at all scales. The calculation depends on data provided by other players in the value chain to perform the assessment.

Assessing circularity of electronic devices in the use phase

Companies can conduct a CTI assessment for the use phase of an electronic device from two perspectives:

- **An individual** seeking to understand the circularity of the electronic device in use;
- **A company** using electronic devices wishing to understand the circularity of the device or portfolio of devices and potentially to gaining insights into procurement criteria or the functioning of internal repair and refurbishment activities.

In this sector guidance, the focus of **the use phase is primarily on companies using electronic devices**.

Step 1 - Scope

Companies define the scope of the assessment by answering by answering key questions explained in the first part of this document:
Part 1 – General CTI explanation.

Step 2 - Select

CTI offers a menu of indicators that enable the company to answer the questions from the scoping step. The tables below offer guidance on selecting indicators for specific activities based on their materiality and usefulness in providing insights, considering the unique business context of each activity.

We make the following distinctions between the different indicators:

- **Required:** Include the indicator as part of the % material circularity (Close the Loop);
- **Recommended:** We recommend the inclusion of the indicator in the assessment, since the assessment provides relevant insights for the activity in scope;
- **Optional:** The indicator is optional; companies can decide to include it based on their sustainability and business objectives.

Appendix II – Use provides an explanation of the indicators and the reasoning behind their classification as required, recommended or optional.

Table 15: Suggested indicators for Use

Close the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% material circularity	Required	Required	Required
% water circularity	Optional	Optional	Optional
% renewable energy	Optional	Optional	Optional
Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% critical material	Recommended	Recommended	Recommended
% recovery type	Recommended	Recommended	Recommended
On-site water circulation	Optional	Optional	Optional
Actual lifetime	Optional	Recommended	Optional
Value the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Circular material productivity	Optional	Optional	Optional
CTI revenue	Recommended	Recommended	Recommended
Impact of the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
GHG impact	Optional	Optional	Optional
Nature impact	Optional	Optional	Optional

Step 3 - Collect

Step 3 explains how to collect data for: % material circularity, % critical material, % recovery type and actual lifetime.

To perform a CTI assessment, users of electronic devices can gather primary data from various up- and downstream value chain partners. Collecting primary data ensures high accuracy and reliability in the assessment. Depending on the company's position in the value chain, they may need to request data from multiple partners to perform the assessment. If primary data is unavailable, they can rely on secondary sources like external databases or publications.

Figure 16 shows potential sources of primary data, including manufacturing and preparation for reuse companies for inflow data and preparation for reuse and recyclers for outflow data.

Calculating the selected indicators requires multiple data points. A company must **carefully consider which data to include or exclude** and the level of granularity.

Figure 16: Potential sources of primary data

	Upstream			Own Operations	Downstream	
Flow	**Inflow** Data Flow →			**Company boundary**	**Outflow** ← Data Flow	
Activity	**Component, contracted and OEM manufacturing**	**Retail and distribution**	**Preparation for reuse services**	**Use**	**Preparation for reuse services**	**Recycling**
Potential data points	→ Product/ component quantities → Product/ component weight → Material specifications → Critical materials → Recovery potential → Waste	→ Product/ component weight → Product/ component specifications	→ Product/ component weight → Recovery potential	→ Product/component quantities → Product/component weight → Actual lifetime → Actual recovery	→ Product/ component weight → Recovery potential → Actual recovery	→ Material weight → Critical materials → Actual recovery
Datal point level	Product or component level	Product level	Product or component level	Product level	Product or component level	Material level
Potential data sources	→ Procurement and sales data → Material safety data sheets (MSDS) → Bill of Materials (BOM) → Disassembly or repair reports → Waste reports	→ Material safety data sheets (MSDS) → Bill of Materials (BOM)	→ Disassembly or repair reports → Laboratory and testing reports	→ Procurement and sales data → EoL service providers → Waste handler reports	→ Disassembly or repair reports → Waste reports	→ Recycling reports → Material tracking sheets → Certificates → Laboratory and testing reports → Waste reports

1 ***Close the Loop***

→ To calculate: % material circularity

% circular inflow (per material flow)

Circular inflow is split into two types of inflow: renewable and non-virgin inflow. While renewable materials are one of the two types of circular inflow, we have intentionally excluded them in the rest of this chapter as companies contributing to this guidance do not expect bio-based materials to have a significant impact on the production of electronic products.

For more context refer to the Circular Electronics System Map.

Non-virgin inflow

This section exclusively refers to "non-renewable non-virgin" flows and refers to previously used (secondary) materials, components or products. Appendix III provides more information on non-virgin inflow.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- Weight of the material/component/product in scope of the assessment
- Material, component or product specifications:
  - Virgin (weight or %)
  - Non-virgin (weight or %)

2. Include/exclude

Include

- Information on the quantities, weight and specifications of materials, components or products components in the devices being used
- Information on the quantities, weight and specifications of materials or spare parts added to a second-hand device during the prepare for reuse phase because damaged parts needed to be replaced, e.g., broken screens or batteries

Exclude

- Information not directly related to the use of the product, such as administrative activities
- Data on the energy consumed during the production process (use the % renewable energy indicator here)

3. Level of detail of the data

For newly produced devices, the most precise measurement of non-virgin inflow can be achieved by collecting the mass of each inflow at the material level, as different materials in electronic devices can have varying degrees of non-virgin content. Obtaining this data for every material present in the device can be challenging for a company and requires information from upstream suppliers such as the retailer, manufacturing companies etc.

When dealing with second-hand devices, the non-virgin inflow can be evaluated at the product level if the product has been previously used and is being reused. It is important to consider any materials or components that may have been added during the preparation for reuse phase to replace damaged parts, as these additions could be virgin and thus lower the overall percentage of non-virgin inflow.

Example for a newly produced device:

A company procures and uses laptops for its employees. Based on BoM documents from the OEM the following information is available: 85% of materials are virgin materials and 15% of materials are pre-consumer recycled content.

The non-virgin inflow for the laptop can be calculated as follows:

- 15% recycled content (material level)
- 85% virgin raw materials (material level)

Total % circular inflow: 15% non-virgin inflow (recycled content)

4. Recommendations for data collection

To begin collecting data on non-virgin inflow, a company can follow these steps:

Newly produced products:

- Contact the manufacturer or retailer of the product in scope and request information on the weight and material specifications
- Set material specifications during the procurement process to gain insights into the minimum use of non-virgin inflow and influence the use of materials in used devices

In case engagement on inflow data doesn't lead to the required data points, the following option exist:

- Research on the typical material composition of the materials, components or products can be conducted using external databases or research publications on the average non-virgin content used.

Second-hand devices:

- Contact the manufacturing company, retailer or partner responsible for the preparation for reuse (e.g., repair) of the electronic device and request information on the weight and material specifications including information on the specifications of materials or components added during the preparation for reuse activities.

In case engagement on inflow data doesn't lead to the required data points, the following option exist:

- Research on typical repair, refurbishment and remanufacturing processes can be conducted using external databases or research publications on exchanged materials or components during the preparation for reuse und their average non-virgin content used.

% circular outflow (per material flow)

Circular outflow is determined by multiplying the % recovery potential and % actual recovery of product, components and materials.

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? Appendix III provides more information on the recovery potential.

1. Data points required

- The material, component, product, business unit and company levels require the following information:
- Weight of the material/component/product
- % of the weight of the material, component, product that is potentially recoverable by design

2. Include/exclude

Include

- Recovery potential of:
  - Materials, e.g., what % of the materials can be recycled
  - Components, e.g., can a component be disassembled and prepared for reuse
  - Products, e.g., what % of the whole product can be disassembled and prepared for reuse

Exclude

- Exclude data points that do **not directly contribute to assessing the recovery potential** of materials, components or products in scope, such as information on unrelated manufacturing processes or administrative activities.

3. Level of detail of the data

When selecting the level of detail of the data for assessing the recovery potential of the products in use, consider the assessment objectives and the type of recovery desired for an electronic device. **If the aim is to extend the lifetime of the product through repair, refurbishment or remanufacturing, assess the recovery potential on a product level**. This provides valuable insights into the overall recoverability of the product and identifies areas where recovery potential can be enhanced.

If the company, for example, wants to assess the alternative uses of materials recovered through recycling from its electronic devices, it may be more relevant to assess the recovery potential on a material level. This provides valuable insights into how materials such as copper or plastics can be repurposed for other uses instead of recovering and repurposing the entire product.

To ensure accuracy and consistency in calculating the % circular outflow, **calculate the actual recovery on the same data level as the recovery potential,** whether it is to be assessed on a material or component or product level.

Example:

A company procures laptops for its employees to use for work. Based on a disassembly report from the manufacturer or retailer the company gets the following information:

From the final product 80% of the parts can be disassembled and recovered, while 20% of the parts cannot be disassembled in (a technically feasible and economically viable) way that allows them to be replaced or reused in the product. 10% of these components can potentially be recycled and the remaining 10% will need to be disposed of as they are not suitable for recycling or other recovery.

To determine the recovery potential of this laptop, use the following calculation:

- 80% of the final product can be potentially recovered through reuse, repair, refurbishment or remanufacturing of the product (product level)
- 10% of the remaining parts can be recycled (material or component level)
- 10% lost recovery potential due to parts that cannot be recovered in any way and must be disposed of

Total % recovery potential: 90% (80% + 10% potentially recoverable through reuse or recycling)

4. Recommendations for data collection

Defining the recovery potential of an electronic device can present a challenge for the company since most of the information remains with the manufacturing companies. Companies reach out to their up-or downstream suppliers and partners to gather information:

- Request a teardown report that outlines the recoverable portion of materials, components or the entire product based on its design;
- Request recovery potential data from the manufacturing company;
- Consult repair, refurbishing, remanufacturing partners on the recovery potential of devices;
- Use the design principles of the manufacturing company, outlining the recovery potential of the product in scope.

Additionally, more general reports and standards could be used to gain insights into standard recovery potential:

- General design guidance reports on product disassembly;
- Alignment with European recyclability standards for electronic devices (CENELEC) reports to ensure consistency in figures.

Actual recovery

Actual recovery refers to the question: 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. Appendix III provides more information on the actual recovery.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- Weight of the material/component/product
- % of the weight of the material, component, product that is actual recovered

Users play a crucial role in increasing the recovery of electronic devices by influencing their lifespan and end-of-life trajectory. **Their actions can shape the demand and practices of other stakeholders in the value chain**, encouraging manufacturers to design more durable and easily serviceable products. By choosing to return, donate or recycle old devices, users promote responsible disposal practices, leading to resource efficiency and reduced environmental impact.

2. Include/exclude

Include

- Actual recovery of:
  - Materials, e.g., what % of the materials are recycled
  - Components, e.g., how many components are recovered and prepared for reuse
  - Products, e.g., what % of the whole product is being disassembled and prepared for reuse
- Actual recovery of operational waste that directly results from the preparation for reuse, e.g., what % of broken parts that had to be exchanged during repair, remanufacturing or refurbishment were recycled or recovered otherwise afterwards.

Exclude

- Waste not directly related to the retail of devices, e.g., office waste
- Water consumption and contamination related to retail operations (use % water circularity here)
- Emissions from sources not directly associated with retail operations itself, such as emissions from employee commuting or unrelated facility activities.

3. Level of detail of the data

To ensure accuracy and consistency in calculating the % circular outflow, it's crucial to determine the actual recovery on the **same data level as the recovery potential was determined**. For example, if the company determined the recovery potential on a product level because the aim is to extend the product lifetime, then it should also assess the actual recovery on a product level.

When calculating the actual recovery, it is important to collect data on the mass of the material, part or product actually recovered compared to the overall mass of the material, component or product.

The level of detail of the data is dependent on the type of recovery the company aims for.

- **Repair:** Takes place at either component or full product level. Request data on the weight of the repaired component or product.
- **Refurbishing:** Takes place at component or full product level (e.g., replacement of screens, tiles). Request data on the weight of the component or product placed onto market after the refurbishing process.
- **Remanufacturing:** Takes place at component level (e.g., replacement of the PCB). Request data on the weight of the component or product placed onto market after the remanufacturing process.
- **Recycling:** Takes place at material, component or full product level (e.g., aluminum is recovered through recycling). Request data on the weight of the materials ending up in recycling.

Example:

Suppose a company procures and uses laptops for its employees. Based on repair reports from the end-of-life product management partner the company gets the following information:

From the final product, on average 75% of the parts are disassembled and recovered. From the 25% of the parts that cannot be disassembled in a technically feasible and economically viable way, 5% of the materials are recycled and the remaining 20% are considered operational waste and being disposed of.

To determine the actual recovery of this laptop, use the following calculation:

- 75% of the final product are recovered through reuse, repair, refurbishment or remanufacturing of the product (product level)
- 5% of the remaining parts are recycled (material or component level)
- 20% disposed parts as they are not recovered in any way

Total % actual recovery: 80% (75% + 5% recovery through reuse or recycling)

% circular outflow: 72% (% potential total recovery (90%) * % actual recovery (80%))

4. Recommendations for data collection

Start the **assessment of outflow streams**, such as the electronic devices and waste, **separately**. This approach allows for a more thorough analysis of potential areas for improvement and optimization of the circular outflow. Additionally, certain regulations, such as the CSRD, may require differentiation between waste and material outflows.

The company could explore actual recovery data through various methods:

- **Partner** with repair, refurbishing or remanufacturing companies to obtain actual recovery data;
- Use **regional or national recovery rates** as benchmark data for more accurate calculations if direct data is not available.

Important reflection points on data collection: Time gap between placing product on the market and recovery of the product.

Electronic devices stay in use on average for 4.5 years,[35] which means it is not possible to reflect the actual recovery of a product that just been introduced on the market. In that case, companies may:

- Use actual recovery data for the previous type of the product of assessment and use the recovered weight-and total weight place on market for the assessment.
- Use proxy data for similar products (based on country/continental average) for the products that are not part of an own take-back scheme, etc.

CTI use case – AT&T

AT&T provides more than 100 million consumers in the US with communications experiences across mobile and broadband. The company believes all electronic devices should be reused, refurbished or recycled. Refurbishing and recycling electronic devices contributes to a circular economy and helps create more affordable product options for consumers

AT&T requires that all US device recycling and salvage vendors maintain an R2 certification. R2 is a comprehensive global certification awarded to facilities that adhere to the R2 responsible electronics recycling standards, which cover areas such as worker health and safety, environmental protection, chain-of-custody reporting and data security. The information on the recovery of phones could be used for the % actual recovery in a circularity assessment with the CTI framework.

Devices come back to AT&T through trade-in, upgrade and insurance programs. AT&T is also piloting a customer take-back campaign aimed at collecting older generation smartphones no longer viable for trade-in programs and circulating them back into the economy.
The company reaches out to customers having devices suitable for trade-in and upgrade, creates greater visibility on landing pages for these trade-in and upgrade programs and offers in-store recycling options.

To obtain the right level of data on the actual recovery, AT&T vocalizes the level of detail the company would like to see from partners as pertains to handsets reused, waste diverted, product-specific data and potential emissions diverted. Suppliers have shared feedback highlighting the positive impact of working together.

2 ***Optimize the Loop***

→ To calculate: % critical material inflow % recovery type

% critical material

Critical materials are materials prone to becoming scarce in the relatively near future and are difficult to substitute without hampering functionality. Several institutions have identified critical raw materials. The EU, for example, identified 34 raw materials in 2023.[36] **Refer to existing definitions and classifications or critical materials**, such as those developed by the **European Union** or the **United States**. These definitions typically consider factors such as the economic importance of the material, the risks associated with its supply and its importance to emerging technologies. **Appendix III** provides more information on critical (raw) material inflow.

1. Data points required

For material, component, product, business unit and company level the company needs to have the following data points:

→ Weight of the critical material in the component or product in scope

→ Weight of the material/component/product in scope

2. Include/exclude

Include

→ All critical materials present in the components or products in scope of the assessment

Exclude

→ Critical materials that are not directly related to the component or products in scope of the assessment

3. Level of detail of the data

Data for the critical material inflow indicator should be collected at the material level. By analyzing critical materials at the material level, it is easier to identify risks and opportunities to support the recirculation of scarce materials and improve the circularity of critical materials.

4. Recommendations for data collection

Collecting the data on the use of critical raw materials could be difficult due to limited influence on the use of materials. Companies could take the following action to collect data on critical raw materials:

→ Perform a teardown of the device in scope or request a teardown report at the manufacturer to gain insights into the use of critical raw materials.

If a company is not able to collect direct information on critical materials contained in the component or product from its suppliers, it is possible to use benchmark data on typical material compositions in components or products. Look for **component/product-specific material compositions** to make the most accurate assumptions. Among others specific research performed on the materials contained in components by taking the components apart.

Example:

A company can use a variety of proxy or benchmark data for specific electronic devices by using external research through online resources such as:

→ **Visualizing the Critical Metals in a Smartphone**

→ **Metallic resources in smartphones**

→ **Raw materials in a laptop**

→ **Recycled material criticality for laptops**

→ **Raw Materials in the Battery Value Chain**

→ **Critical Raw Materials for Strategic Technologies and Sectors in the EU**

→ **The semiconductor and critical raw material ecosystem at a time of great power rivalry**

% recovery type

For the Optimize the Loop module, the % recovery type provides a deep exploration of higher value retention strategies within company reach. % recovery type is applied to % actual recovery. Appendix III provides more information on the recovery type.|

1. Data points required

The material, component, product, business unit or company levels require the following information:

- The weight or percentage of material, component or product actually recovered **per type of recovery**
- The weight or percentage of waste that directly results from the preparation for reuse process for secondary devices actually recovered **per type of recovery**

2. Include/exclude

Include

- Recovery of material, components or products in scope of the assessment
- Waste that directly results from the preparation for reuse process for secondary devices, e.g., replacement broken parts during repair services

Exclude

- Recovery of materials not directly related to the recycling process, e.g., office waste

3. Level of detail of the data

As the recovery type is applied to the percentage of actual recovery, determine the recovery type at the respective level used for actual recovery to ensure accuracy and consistency.

Example:

A company uses laptops and the actual recovery was determined as illustrated under actual recovery, the recovery type can be determined as follows:

- 75% of the final product is reused (product level)
- 5% of the remaining parts are recycled (material or component level)
- 20% of the parts are disposed of as they are not recovered in any way

4. Recommendations for data collection

To determine the recovery % per type, assess the performance of the recovery per type for each material, component or product. Categorize the recovery types based on the specific processes implemented (reuse, repair, remanufacturing/refurbishing, recycling). Engage with downstream partners such as companies offering repair or refurbishing services, recyclers or waste handlers. This allows for a better understanding of how these materials are reprocessed or reused.

To evaluate the recovery type, a company can consider the following data points:

- Build a database presenting a detailed breakdown of products taken back to the retailer that undergo repair, refurbish, remanufacturing activities;
- Research information on recycling initiatives at the component level, including the types of components recycled and their corresponding recovery rates;
- Research information on the refurbishing or remanufacturing processes, particularly the specific materials, components or products involved and their overall recovery percentages during these activities;

Companies may use more general reports and standards to gain insights into assessment of recovery types, such as developing customer surveys to gain insights into the lifetime extending or end-of-life practices most used by customers per product type (potentially aligned with WEEE product categories).

CTI use case – AT&T

AT&T provides more than 100 million consumers in the US with communications experiences across mobile and broadband. The company believes all electronic devices should be reused, refurbished or recycled. Refurbishing and recycling electronic devices contributes to a circular economy and helps create more affordable product options for consumers.
As part of AT&T's take-back efforts, the company requests reporting information from phone reuse and recycling partners on the final treatment of recovered phones. The company then splits the information according to the different types of recovery, thereby aligning with the Optimize the Loop indicator – % recovery type.

This leads to a split between reused/sold recycling and landfill:

% recovery type for devices through AT&T	2022
Total number of consumer devices reused or recycled through AT&T	14.9 million
Materials from take-back programs reused or sold	89.0%
Materials from take-back programs recycled	11.0%
Materials from take-back programs landfilled	0.0%

Actual lifetime

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. 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".[37] **Appendix III** provides more information on the actual lifetime.

1. Data points required

- Product actual lifetime in years
- Average product actual lifetime in years

2. Include/exclude

Include

- Actual lifetime of electronic devices in scope of the assessment

Exclude

- Actual lifetime of electronic devices not directly related to the device in scope that could lead to wrongfully determining average product lifetime

3. Level of detail of the data

To accurately evaluate the lifespan of electronic devices, it's beneficial to assess it at the product level rather than the material level. This allows companies to understand the device's durability and identify areas for improvement in use patterns and recovery methods. By doing so, companies can make informed decisions, contribute to the circular economy and extend the lifespan of their devices. Additionally, the data generated by companies regarding the lifespan and end-of-life treatment of their devices can be valuable to other partners in the value chain.

4. Recommendations for data collection

Collecting the data needed to calculate the actual lifetime can be challenging for a company as it requires data from up- and downstream suppliers.

The **product actual lifetime** can be obtained by collecting data on the lifespan of individual devices, either through information from OEMs, retailers or through data collected from repair or refurbishing services. This data can provide insights into how long individual devices are being used before becoming obsolete or requiring replacement.

The **average product actual lifetime** can be obtained by analyzing data on the lifespan of a larger sample of devices. companies could draw from their own past experiences or consider industry-wide data. This data can provide insights into the typical lifespan of electronic devices and can serve as a benchmark for comparison with other similar devices a company may own or intend to purchase.

Value chain activity 5: Preparation for reuse

Repair, refurbish, remanufacture

A company whose main business activity is specializing in repairing, refurbishing or remanufacturing electronic devices with the aim of extending their lifespan by restoring them to their original condition or upgrading them to meet current standards. The range of services includes repairing damaged components, replacing worn-out parts, upgrading software and hardware and cleaning and refurbishing the device exterior. Remanufacturing involves disassembling the device, replacing any worn-out or damaged components and reassembling it to its original specifications.

Step 1 - Scope

Companies define the scope of the assessment by answering by answering key questions explained in the first part of this document:
Part 1 – General CTI explanation.

Step 2 - Select

CTI offers a menu of indicators that enable the company to answer the questions from the scoping step. The tables below offer guidance on selecting indicators for specific activities based on their materiality and usefulness in providing insights, considering the unique business context of each activity.

We make the following distinctions between the different indicators:

- **Required:** Include the indicator as part of the % material circularity (Close the Loop);
- **Recommended:** We recommend the inclusion of the indicator in the assessment, since the assessment provides relevant insights for the activity in scope;
- **Optional:** The indicator is optional; companies can decide to include it based on their sustainability and business objectives.

Appendix II – Use provides an explanation of the indicators and the reasoning behind their classification as required, recommended or optional.

Table 16: Suggested indicators for Preparation for reuse

Close the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% material circularity	Required	Required	Required
% water circularity	Optional	Optional	Optional
% renewable energy	Optional	Optional	Optional
Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% critical material	Recommended	Recommended	Recommended
% recovery type	Recommended	Recommended	Recommended
On-site water circulation	Optional	Optional	Optional
Actual lifetime	Optional	Recommended	Optional
Value the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Circular material productivity	Optional	Optional	Optional
CTI revenue	Recommended	Recommended	Recommended
Impact of the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
GHG impact	Optional	Optional	Optional
Nature impact	Optional	Optional	Optional

Step 3 — Collect

Step 3 explains how to collect data for: % material circularity, % critical materials, % recovery type and actual lifetime.

To perform a CTI assessment, prepare for reuse companies can **gather primary data from various up- and downstream value chain partners**. Depending on the company's position in the value chain, it may need to request data from multiple partners to perform the assessment. Collecting primary data ensures high accuracy and reliability in the assessment. If primary data is unavailable, companies can rely on secondary sources like external databases or publications.

Figure 16 shows potential sources of primary data, including manufacturers or retailers for inflow data and recyclers for outflow data.

Calculating the selected indicators requires multiple data points. A company must **carefully consider which data to include or exclude** and the level of granularity.

Figure 16: Potential sources of primary data

	Upstream			Own Operations	Downstream	
Flow	Inflow (Data Flow →)			Company boundary	Outflow (← Data Flow)	
Activity	**Component, contracted and OEM manufacturing**	**Retail and distribution**	**Use**	**Preparation for reuse services**	**Use**	**Recycling**
Potential data points	→ Product/ component quantities → Product/ component weight → Material specifications → Critical materials → Recovery potential → Waste	→ Product/ component weight → Product/ component specifications	→ Product/ component quantities → Product/ component weight	→ Product/component quantities → Product/component weight → Actual lifetime → Actual recovery	→ Actual lifetime → Actual recovery	→ Material weight → Critical materials → Actual recovery
Datal point level	Product or component level	Product level	Product level	Product or component level	Product level	Material level
Potential data sources	→ Procurement and sales data → Material safety data sheets (MSDS) → Bill of Materials (BOM) → Disassembly or repair reports → Waste reports	→ Material safety data sheets (MSDS) → Bill of Materials (BOM)	→ Procurement and sales data	→ Procurement and sales data → Disassembly or repair reports → Laboratory and testing reports → Waste reports	→ Procurement and sales data → EoL service providers → Waste handler reports	→ Recycling reports → Material tracking sheets → Certificates → Laboratory and testing reports → Waste reports

1 ***Close the Loop***

→ To calculate: % material circularity

% circular inflow (per material flow)

Circular inflow is split into two types of inflow: renewable and non-virgin inflow. While renewable materials are one of the two types of circular inflow, we have intentionally excluded them in the rest of this chapter as companies contributing to this guidance do not expect bio-based materials to have a significant impact on the production of electronic products.

For more context refer to the **Circular Electronics System Map**.

Non-virgin inflow

This section exclusively refers to "non-renewable non-virgin" flows and refers to previously used (secondary) materials, components or products. **Appendix III** provides more information on non-virgin inflow.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- Weight of the material/component/product in scope of the assessment
- Material, component or product specifications:
  - Virgin (weight or %)
  - Non-virgin (weight or %)

2. Include/exclude

Include

- Information on the quantities, weight and specifications of materials, components or products procured or collected to be prepared for reuse through repair, refurbishment or remanufacturing
- Information on the quantities, weight and specifications of materials or spare parts procured to replace broken or worn-out components of recovered devices

Exclude

- Data from processes that are not directly related to the preparation of reuse for electronic products, such as administrative activities or unrelated manufacturing processes
- Data on the energy or water consumed during the production process (use the % renewable energy and %water circularity indicator here)

3. Level of detail of the data

The non-virgin inflow can be determined at the **product level** as all products that enter the company have been previously used. The total weight of the device entering the company boundary is considered 100% non-virgin inflow.

Companies need to **assess any materials or components added** during the preparation for reuse phase to replace damaged or outdated parts separately, as these could be made out of virgin material and thus lower the overall percentage of non-virgin inflow. For the most accurate calculations of the % non-virgin inflow for added materials or parts, it's best to do so at the **material or component level**.

Example:

A company takes back a phone with a total mass of 200 g. The battery (40 g), home button (5 g) and screen (20 g) of the phone are broken and need to be replaced. Based on information from the component manufacturer the following information are available:

- the battery is a new battery made from virgin materials
- the home button is made from recycled plastic
- the screen is made from bio-based glass.

The non-virgin inflow for the repaired phone can be calculated as follows:

- 67.5% recovered phone (product level) – 135 g non-virgin inflow (200 g total mass – 65 g replaced parts)
- 2.5% recycled materials from replaced home button (component level)
- 30% virgin materials from replaced battery (component level)

Total % circular inflow: 70% (70% non-virgin inflow from 67.5% recovered phone + 2.5% recycled materials)

4. Recommendations for data collection

The most crucial part when collecting data for the % non-virgin inflow is to get data on materials or components added to the product during the preparation of reuse activities to replace damaged or outdated parts. To begin collecting data a company can follow these steps:

- Contact the suppliers of spare parts or materials and request information on the material specifications;
- Track and document the weight and number of devices entering the repair, refurbishing, remanufacturing process.

In case engagement on inflow data doesn't lead to the required data points, the following option exists:

- Conduct research on the typical material composition of the materials or parts using external databases or research publications on the average non-virgin content used in production.

% circular outflow (per material flow)

Circular outflow is determined by multiplying the % recovery potential and % actual recovery of product, components and materials.

Recovery potential

Recovery potential refers how the company designs 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 such that they are biodegradable.

Appendix III provides more information on the recovery potential.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- Weight of the material/component/product
- % of the weight of the material, component, product that is potentially recoverable by design

A company that specializes in repairing, refurbishing or remanufacturing electronic devices usually does not have direct influence on the product design. These companies have a deep understanding of the potential for recovering and reusing components and materials from devices based on their operations. This knowledge can be valuable for manufacturers, as it can inform product design decisions that improve the recovery potential.

2. Include/exclude

Include

- Information on the **recovery potential of the product** in scope of the assessment
- Information on the **recovery potential of damaged or obsolete materials or components** of the product in scope that needed replacing during the preparation for reuse phase

Exclude

- Data points that do **not directly contribute to assessing the recovery potential** of materials, components or products, such as information on unrelated manufacturing processes or administrative activities.

3. Level of detail of the data

Companies specializing in repair, refurbishment or remanufacturing aim to extend the lifetime of whole products. To assess the recovery potential of a product and identify areas for improvement, it's recommended to do this at a product level.

For **materials or parts replaced** due to damage or obsolescence, the recovery potential can be assessed **on a material or component level**. Replaced metal, plastic or glass components can be recycled. In such cases, it can be more insightful to determine the recovery potential of a material.

To ensure accuracy and consistency in calculating the % circular outflow, **calculate the actual recovery on the same data level as the recovery potential,** whether it is assessed on a material or product level.

Example:

A company recovers a phone; 80% of the phone's parts can be disassembled and replaced, while 20% of the parts cannot be disassembled in a way that allows them to be replaced or reused in the product; 10% of these components can be recycled and the remaining 10% will need to be disposed of. To determine the recovery potential of this phone, use the following calculation:

- → 80% recovery potential through reuse, repair, refurbishment or remanufacturing of the product (product level)
- → 10% recovery potential through recycling of replaced materials or components (material or component level)
- → 10% lost recovery potential due to parts that cannot be recovered in any way and must be disposed of

Total % recovery potential: 90% (80% product reuse potential + 10% component or material recycling potential)

4. Recommendations for data collection:

A company specializing in repairing, refurbishing or remanufacturing electronic devices **usually has a good understanding of the recovery potential of a device.** A company can gather information in the following way:

- → Request a teardown report by external party or perform a teardown internally, outlining the portion of materials, (sub) component or full product that could be recovered.
- → Use the design principles of the manufacturing company/OEM, outlining the recovery potential of components/material used in the product in scope.

If this information is not available, a company can:

- → Use benchmark data, such as information on the recyclability of certain materials or components (e.g., batteries)
- → Follow general design guidance reports on product disassembly

Actual recovery

Actual recovery refers to the question: 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. Appendix III provides more information on the actual recovery.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- → Weight of the material/component/product
- → % of the weight of the material, component, product actually recovered

Companies specializing in the repair, refurbishment or remanufacturing of electronic devices play a critical role in increasing the actual recovery of devices. The companies will receive devices from end-users and placed them back on the market after repair, refurbish, remanufacturing.

The actual recovery for these products is typically high, with "reuse" as the predominant recovery type. The device is reused after the repair, refurbish, remanufacturing activities. The company should consider what happens to any materials or parts exchanged during the repair, refurbishment or remanufacturing process, as these are recoverable in different ways, such as recycling screens or batteries. Neglecting to recover these exchanged parts can result in a lower actual recovery percentage for repaired, refurbished or remanufactured devices.

2. Include/exclude

Include

- → Information on the **actual recovery of the product** in scope of the assessment
- → Information on the **actual recovery of damaged or obsolete materials or components** of the product in scope that needed to be replaced during the preparation for reuse phase
- → **Operational waste** that directly results from the preparation for reuse process and not recovered

Exclude

- Waste not directly related to the preparation for reuse process
- Water consumption and contamination during preparation for reuse process (use % water circularity here)

3. Level of detail of the data

To ensure accuracy and consistency in calculating the % circular outflow, determine the actual recovery on the same data level as the recovery potential. If the recovery potential was determined on product level because the aim is to extend the product lifetime, then the actual recovery should also be determined on product level.

Example:

A company recovers a phone. If the recovery potential was determined as illustrated under “recovery potential” the assessment of the actual recovery could look as follows:

- 80% of the product was actually recovered and reused (product level)
- Only 5% of the replaced materials or components that could have been recovered (based on the recovery potential) through recycling were actually recycled (at the material or component level)
- 15% of the product was lost potential due to parts that could not be recovered in any way and were disposed of

Total % actual recovery: 85%

% circular outflow: 76,5% ((% recovery potential (90%) * % actual recovery (85%))

4. Recommendations for data collection

The most significant challenge is gaining a comprehensive understanding of the recovery process of replaced materials and components. A company can gather information in the following way:

- Collaborate with downstream partners such as recyclers or waste handlers on the recovery method of materials and components

In cases where primary data on the recovery type is unavailable, companies can use benchmark data, such as the percentage of a phone that is repaired versus recycled. Use benchmark data specific to the region to ensure more precise calculations.

2 ***Optimize the Loop***

→ To calculate: % critical material inflow and % recovery type

% critical material

Critical materials are materials prone to becoming scarce in the relatively near future and are difficult to substitute without hampering functionality. Several institutions have identified critical raw materials. The EU, for example, identified 34 raw materials in 2023.[38] First **refer to existing definitions and classifications or critical materials**, such as those developed by the European Union or the United States. These definitions typically consider factors such as the economic importance of the material, the risks associated with its supply and its importance to emerging technologies. Appendix III provides more information on critical (raw) material inflow.

1. Data points required

For material, component, product, business unit and company level the company needs to have the following data points:

- Weight of the critical material in the component or product in scope
- Total weight of the material/component/product in scope

2. Include/exclude

Include

- All critical materials present in the components or products in scope of the assessment

Exclude

- Critical materials that are not directly related to the component or products in scope of the assessment

3. Level of detail of the data

Collect data for the critical material inflow indicator at the material level. By analyzing critical materials at the material level, it is easier to identify risks and opportunities to support the recirculation of scarce materials and improve the circularity.

Obtaining data on critical materials at a component or product level, e.g., X% of an electronic device, can be challenging and may not be suitable for use because different critical materials may have different implications, such as varying exposure to price volatility or availability.

4. Recommendations for data collection

To collect data on critical raw materials, companies may:

- Perform a teardown of the device or component in scope or request a teardown report at the manufacturing company/OEM or at the retailer to gain insights into the use of critical raw materials.
- Contact the internal departments (e.g., R&D/design/product development) on the raw materials expected – and materials uncovered during repair, refurbish or remanufacturing process.

It is possible to use benchmark data on typical material compositions in electronic devices. Look for **device-specific material compositions** to make most accurate assumptions.

Example:

A company can use a variety of proxy or benchmark data for specific electronic devices by using external research through online resources such as:

- Visualizing the Critical Metals in a Smartphone
- Metallic resources in smartphones
- Raw materials in a laptop
- Recycled material criticality for laptops
- Raw Materials in the Battery Value Chain
- Critical Raw Materials for Strategic Technologies and Sectors in the EU
- The semiconductor and critical raw material ecosystem at a time of great power rivalry

% recovery type

For the Optimize the Loop module, the % recovery type provides a deep exploration of higher value retention strategies within company reach. Apply the % recovery type to % actual recovery. Appendix III provides more information on the recovery type.

When a company repairs, refurbishes or remanufactures devices, the actual recovery for these products is typically high, with "reuse" being the predominant recovery type. Consider what happens to any materials or parts exchanged during the repair, refurbishment or remanufacturing process, as these are recoverable in different ways, such as recycling screens or batteries.

1. Data points required

The material, component, product, business unit or company levels require the following information:

- The weight or percentage of material, component or product actually recovered **per type of recovery**
- The weight or percentage of replaced materials and parts such as broken screens or batteries that directly results from the preparation for reuse process actually recovered **per type of recovery**

2. Include/exclude

Include

- Materials, components or products in scope of the assessment
- Damaged or obsolete materials or components of the product in scope that were actually recovered

Exclude

- Materials or components not directly related to product in scope
- Materials or components of the product that were not recovered

3. Level of detail of the data

As the recovery type is applied to the percentage of actual recovery, determine the recovery type at the respective level used for actual recovery to ensure accuracy.

Example:

A company recovers a phone and the actual recovery was determined as illustrated under “actual recovery”. The recovery type can be determined as follows:

- 80% reuse by customers (product level)
- 5% recycling (at the material or component level)
- 15% of the product was disposed of in this cycle

4. Recommendations for data collection

The most significant challenge is gaining a comprehensive understanding of the recovery process for replaced materials and components. To achieve this, companies must collaborate with downstream partners such as recyclers or waste handlers.

In cases where primary data on the recovery type is unavailable, companies can use benchmark data, such as the percentage of a phone that is repaired versus recycled. Use benchmark data specific to the region to ensure more precise calculations.

Actual lifetime

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. 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".[39] **Appendix III** provides more information on the actual lifetime.

1. Data points required

- Product actual lifetime in years
- Average product actual lifetime in years

2. Include/exclude

Include

- Actual lifetime of electronic devices in scope of the assessment

Exclude

- Actual lifetime of electronic devices not in scope of the assessment

3. Level of detail of the data

Assess the actual lifetime of electronic devices on a product level since the lifetime is dependent on various factors, including its design, manufacturing and use patterns.

Companies can obtain a more accurate assessment of the product's durability and identify areas for improvement in their product design and recovery processes.

4. Recommendations for data collection

Companies specializing in repairing, refurbishing or remanufacturing electronic devices contribute to extending a product's actual lifetime by recirculating it into a next use cycle. **The company can add the average actual lifetime of the electronic devices it has prepared for reuse to the average actual lifetime the product would have had without being prepared for reuse.** The company determines how many additional years it has added to the product's actual lifetime and divide this by the average product lifetime.

For example, Rebuy, a company that specializes in refurbishing and reselling consumer products, assesses the number of additional use years it has generated through its operations. Key figures of Rebuy show they have given 442k electronics products a new life in 2022. Additionally, 1.3 million usage years were generated for consumer products in 2022.[40]

Value chain activity 6: Recycling

Recycling

The recycling of electronic devices refers to the process of recovering valuable materials and components from discarded or obsolete electronic products. This process involves disassembling the electronic devices, separating the different materials and processing them to extract the valuable metals, plastics and other materials. The recovered materials can then be used to manufacture new products, reducing the need for virgin materials and conserving natural resources.

Step 1 - Scope

Companies define the scope of the assessment by answering by answering key questions explained in the first part of this document:
Part 1 – General CTI explanation.

Step 2 - Select

CTI offers a menu of indicators that enable the company to answer the questions from the scoping step. The tables below offer guidance on selecting indicators for specific activities based on their materiality and usefulness in providing insights, considering the unique business context of each activity.

We make the following distinctions between the different indicators:

- **Required:** Include the indicator as part of the % material circularity (Close the Loop);
- **Recommended:** We recommend the inclusion of the indicator in the assessment, since the assessment provides relevant insights for the activity in scope;
- **Optional:** The indicator is optional; companies can decide to include it based on their sustainability and business objectives.

Appendix II – Recycling provides an explanation of the indicators and the reasoning behind their classification as required, recommended or optional.

Table 17: Suggested indicators for recycling

Close the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% material circularity	Required	Required	Required
% water circularity	Recommended	Recommended	Recommended
% renewable energy	Recommended	Recommended	Recommended
Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% critical material	Recommended	Recommended	Optional
% recovery type	Recommended	Recommended	Recommended
On-site water circulation	Optional	Optional	Recommended
Actual lifetime	Optional	Optional	Optional
Value the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Circular material productivity	Not recommended	Not recommended	Not recommended
CTI revenue	Optional	Optional	Optional
Impact of the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
GHG impact	Recommended	Recommended	Recommended
Nature impact	Optional	Optional	Optional

Step 3 - Collect

Step 3 explains how to collect data for: % material circularity, % critical material, % recovery type and actual lifetime.

To perform a CTI assessment, recyclers can **gather primary data from various up- and downstream value chain partners**. Depending on the company's position in the value chain, they may need to request data from multiple partners to perform the assessment. Collecting primary data ensures high accuracy and reliability in the assessment. If primary data is unavailable, companies can rely on secondary sources like external databases or publications.

Figure 17 shows potential sources of primary data, including manufacturers or retailers for inflow data and manufacturers using recycled materials for outflow data.

Calculating the selected indicators requires multiple data points. A company must **carefully consider which data to include or exclude** and the level of granularity.

Figure 17: Potential sources of primary data

	Upstream			Own Operations	Downstream
Flow	**Inflow** Data Flow →			**Company boundary**	**Outflow** ← Data Flow
Activity	**Component, contracted and OEM manufacturing**	**Retail and distribution**	**Use**	**Recycling**	**Component, contracted and OEM manufacturing**
Potential data points	→ Product/component quantities → Product/component weight → Material specifications → Critical materials → Recovery potential → Waste	→ Product/component weight → Product/component specifications	→ Product/component quantities → Product/component weight	→ Product/component quantities → Product/component weight → Material quantities and weight → Recovery potential → Waste	→ Actual recovery (%of recycled materials used in new products & % of mateirals lost in manufacturing process) → Actual lifetime
Datal point level	Product or component level	Product level	Product level	Product or component level	Material, component or product level
Potential data sources	→ Procurement and sales data → Material safety data sheets (MSDS) → Bill of Materials (BOM) → Disassembly or repair reports → Waste reports	→ Material safety data sheets (MSDS) → Bill of Materials (BOM)	→ Procurement and sales data	→ Procurement and sales data → Disassembly or repair reports → Laboratory and testing reports → Waste reports	→ Procurement and sales data → Product design concepts → Waste reports

1 ***Close the Loop***

→ To calculate: % material circularity

% circular inflow (per material flow)

Circular inflow is split into two types of inflow: renewable and non-virgin inflow. While renewable materials are one of the two types of circular inflow, we have intentionally excluded them in the rest of this chapter as companies contributing to this guidance do not expect bio-based materials to have a significant impact on the production of electronic products.

Non-virgin inflow

This section exclusively refers to previously used (secondary) materials, components or products, such as recycled materials, second-hand products or refurbished parts. **Companies should process materials entering the manufacturing facility that were not originally part of the product or component at the material level (e.g., solvents, acids or other chemicals).** Appendix III provides more information on non-virgin inflow.

1. Data points required

The material, component, product, business unit and company levels require the following information:

- Weight of the material/component/product
- Material, component or product specifications:
  - Virgin (weight or %)
  - Non-virgin (weight or %)

Example:

An electronic device such as a laptop or mobile phone has already been used upstream, making it non-virgin when it enters the recycling cycle. Such materials, components or products can be considered 100% circular inflow.

2. Include/exclude

Include

- Information on the specification, quantities and weight of materials, components and products entering the company for recycling purposes
- Information on the specification, quantities and weight of materials used or added during the recycling process that were not present in the original materials, components or products

Exclude

- Impacts related to the extraction, production and transportation of raw materials before they reach the recycling facility
- Data from processes that are not directly related to material recycling, such as administrative activities or unrelated manufacturing
- Data on the energy consumed during the recycling process (use the % renewable energy indicator)

3. Level of detail of the data

Recyclers usually receive used products, components or other types of e-waste. The material streams entering the recycling facility can be considered 100% non-virgin, as they have been used before entering the recycling process.

Example:

A recycling facility wants to assess the % circular inflow of the recycling line that processes old electronic office equipment. The company's internal recycling reports show that the e-waste contains no bio-based materials and they are also not in the recycling process.

As all inflow materials entering the recycling process are pre-used, all materials are considered non-virgin. Therefore, the non-virgin inflow is 100%.

The **% circular inflow is 100%** (% non-virgin inflow (100%))

4. Recommendations for data collection

To begin collecting data on non-virgin inflow, a recycling company can follow these steps:

- Identify any materials added to the recycling process;
- If there are no added materials, the non-virgin content of materials entering the recycling process is considered to be 100%;
- If there are any added materials entering the recycling process, collect data on their weight and specifications (virgin or non-virgin).

% circular outflow (per material flow)

Circular outflow is determined by multiplying the % recovery potential and % actual recovery of product, components and materials.

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.)? Appendix III provides more information on the recovery potential.

1. Data points required

The material level requires the following information to calculate the recovery potential:

- Total weight of the material leaving the recycling process.
- The weight or % of the recycled material that can be potentially recycled. Factors impacting the recovery potential are hazardous materials, toxic materials, inseparable materials into mono streams.
- The weight or % of operational waste, such as residues or other parts that are potentially recoverable.

Since the primary output of a recycling company is at the material rather than the component or product level, focus on the **recovery potential of recycled materials for reintroduction into the material cycle**. When collecting data for the recovery potential, the company should consider the **composition of the recycled materials**, as they can have varying recovery potential and future recyclability in subsequent recycling cycles.

Example:

Copper is a prime example of a highly recyclable metal that can be recycled repeatedly without significant quality loss. Its properties, such as conductivity and malleability, remain largely unchanged during recycling, resulting in a recovery potential rate of 100%. In comparison, some plastics experience downcycling, leading to a decline in mechanical properties with each recycling cycle and a recovery potential rate lower than 100%.

Some parts or materials contained in products that enter recycling facilities as e-waste are **not recoverable** in the recycling process and are not considered recyclable waste.

Important note

Material recycling offers valuable information for upstream companies on the potential and actual, recovery of products originating from OEMs (or component manufacturers), retailers or users of the devices.

2. Include/exclude

Include

- Information on the **recovery potential of the recycled materials** (e.g., what % of a certain metal can be recycled in a second recycling cycle after reuse)
- Information on the recovery potential of **residues or operational waste** generated during the recycling process

Exclude

- Information on the **recovery potential of components or products** entering the recycling facility (e.g., repairability or recyclability of components or products)

3. Level of detail of the data

To calculate the recovery potential of recycled materials leaving the recycling facility, collect the mass of each outflow at the material level. To ensure the most accurate calculation of the recovery potential of recycled materials, a recycling company should ideally consider the exact amount or percentage of the material processed in the recycling facility that can be recycled again. In cases where exact data on the recovery potential of materials is not available, companies can use proxy or benchmark data on the amount or percentage of materials that can be recycled again as an alternative.

Example:

A recycling facility wants to assess the recovery potential of its output materials from the recycling line of old electronic office equipment. Based on internal recycling reports, the company has the following information:

Of the total amount of e-waste from old electronic office equipment that enters the recycling facility, 80% can potentially be recycled and 20% cannot be recycled and is considered operational waste.

To determine the recovery potential of this recycling line, companies can use the following calculation:

- → 80% of processed materials can be recycled and reused (material level)
- → 20% lost recovery potential due to parts that cannot be recycled and must be disposed of as operational waste

Total % recovery potential: 80%

4. Recommendations for data collection

If direct data on the recovery potential of materials are not available, companies can use benchmark or proxy data. For the most accurate results, **consider facility and process-specific information**, such as the purity and degree of contamination during a specific recycling process.

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. Appendix III provides more information on the actual recovery.

1. Data points required

The material level requires the following information:

- → Total weight of recycled materials sold to customers;
- → The weight or % of the recycled material actually recovered, i.e., reused;
- → Total weight of operational waste such as residues or other parts;
- → The weight or % of operational waste actually recovered, i.e., reused or recycled again.

When determining the actual recovery for a recycling company, consider the weight of material waste generated during the recycling process that the company will dispose of because it cannot be recycled. Material waste can be generated during the disassembly, sorting and processing stages of the recycling process and can reduce the overall recovery rate of the material.

Example:

The recycling process for batteries can generate material waste in the form of slag or other residues during the processing stage. The disassembly process may generate material waste in the form of damaged or non-recoverable components affecting the actual recovery of the recycling process.

Laptops could be comprised of materials, such as metals or plastics, that are not recoverable through recycling. Additionally, their compact and lightweight design can make them challenging to disassemble and recycle, leading to waste materials or residues that can negatively impact the actual recovery of the recycling process.

2. Include/exclude

Include

- → Recycled materials processed in the recycling facility and sold to customers
- → Operational waste that directly results from the recycling process, e.g., residues or non-recyclable material parts

Exclude

- → Waste released in the air such as dust associated with the recycling process
- → Waste not directly related to the recycling process, e.g., office waste
- → Water consumption and contamination during recycling processes (use % water circularity instead)
- → Emissions from sources not directly associated with the recycling process itself, such as emissions from employee commuting or unrelated facility activities.

3. Level of detail of the data

To calculate the actual recovery of recycled materials leaving the recycling facility and waste generated during the recycling process, collect the mass of each outflow at the material level. **Assessing the actual recovery at the material level allows for the tracking of the amount of each material recovered, as well as the amount lost or wasted.** Use this information to identify opportunities to improve the company's recovery processes and reduce waste.

Example:

A recycling facility wants to assess the actual recovery of its output materials from the recycling line of old electronic office equipment. Based on internal recycling reports and production reports from its manufacturers, the company has the following information:

The manufacturer reused 80% of processed materials; it disposed of 20% of the total e-waste stream that it could not recycle and considered operational waste.

To determine the recovery potential of this recycling line, use the following calculation:

- → 80% of processed materials are recycled and reused by manufacturers (material level)
- → 20% lost recovery due to parts that cannot be recycled and are disposed of as operational waste

Total % actual recovery: 80%

% circular outflow: 64% (% recovery potential (80%) * % actual recovery (80%))

4. Recommendations for data collection

A recycling company that specializes in electronic waste ensures the reuse of a large part of processed materials. While the recycled raw materials require further processing alongside their virgin counterparts, they can ultimately be used to create new electronic devices, thereby extending the life cycle of the materials.

A company should also consider the actual recovery of operational waste such as residues or slag produced during the recycling process when materials are separated and processed.

If direct data on the actual recovery of certain materials are not available, use benchmark data. We recommend using **region-specific benchmark** data to perform more accurate calculations.

2 ***Optimize the Loop***

→ To calculate: % critical material inflow and % recovery type

% critical material

Critical materials are materials prone to becoming scarce in the relatively near future and are difficult to substitute without hampering functionality. Several institutions have identified critical raw materials. The EU, for example, identified 34 raw materials in 2023.[41] First **refer to existing definitions and classifications or critical materials**, such as those developed by the European Union or the United States. These definitions typically consider factors such as the economic importance of the material, the risks associated with its supply and its importance to emerging technologies. Appendix III provides more information on critical (raw) material inflow.

1. Data points required

The material level requires the following information:

- Total weight of all materials entering the recycling process
- Weight or % of critical materials in the components or products entering the recycling process in scope

Note: According to CTI, the percentage of critical material inflow is calculated by dividing the mass of critical materials by the total mass of all linear inflow. For recycling companies, since most of the inflow is non-virgin and the linear inflow is close to zero, this calculation method may provide little valuable insight. Therefore, we recommend that recycling companies deviate slightly from the calculation methodology and divide the mass of critical materials by the total mass of all inflow.

2. Include/exclude

Include

- Materials, components and products that are being recycled
- Other materials, components and products directly related to the recycling process, e.g., materials added during the recycling process

Exclude

- Materials, components and products that are not directly related to the recycling process of materials in scope of the assessment

3. Level of detail of the data

Data for the critical material inflow indicator should be collected at the material level. This allows to identify risks and opportunities to support the recirculation of scarce materials and improve the circularity of critical materials.

4. Recommendations for data collection

Recycling companies could take the actions below to collect data on critical raw materials:

- Perform a teardown of the device or component in scope or request a teardown report at the OEM or retailer to gain insights into the use of critical raw materials.
- Perform a teardown of the device or component in scope or request a teardown report at the company specialized in repair, refurbish or remanufacturing to gain insights into the use of critical raw materials of the reused components or products.
- Contact the internal departments (e.g., R&D/design/product development) to determine the raw materials expected to be used in the repair, refurbishment or remanufacturing process of the electronic devices.

If a recycling company is not able to collect direct information on critical materials contained in the electronic devices from its suppliers, it is possible to use benchmark data on typical material compositions in electronic devices. Look for **device-specific material compositions** to make most accurate assumptions.

% recovery type

For the Optimize the Loop module, the % recovery type provides a deep exploration of higher value retention strategies within company reach. % recovery type is applied to % actual recovery. **Appendix III** provides more information on the recovery type.

For a recycling company that specializes in electronic waste, the most common recovery type is reuse. Although the recycled raw materials must undergo further processing alongside their virgin counterparts, they are eventually reused to create new electronic devices, extending the life cycle of the materials. After the technical lifespan of an electronic device has ended, the materials can potentially be recycled and reused again, further reducing waste and conserving natural resources. Therefore, in most cases the % recovery type for recycled materials is close to 100% reuse.

The recovery type that applies most to residues or slag produced during a recycling process and recovered afterwards is recycling. Residues or slag are often produced during the recycling process when materials are separated and processed. These residues or slag may contain valuable materials that are recoverable and reused, such as metals or minerals. In some cases, residues or slag may also be used for other purposes, such as construction materials or road building. This is a form of reuse, but it is less common for residues or slag than it is for other types of materials.

1. Data points required

The material level requires the following information:

- → The weight or percentage of recycled materials actually recovered **per type of recovery**
- → The weight or percentage of operational waste or residues actually recovered **per type of recovery**

2. Include/exclude

Include

- → Recovery of recycled materials processed in the recycling facility and are sold to customers
- → Recovery of operational waste that directly results from the recycling process, e.g., residues or non-recyclable material parts

Exclude

- → Recovery of materials not directly related to the recycling process, e.g., office waste

3. Level of detail of the data

To calculate the recovery type, assess the recovery type at the material level because the actual recovery is also assessed at the material level to maintain consistency throughout the calculations. By assessing the recovery type at the material level, recycling companies can focus on the specific properties and characteristics of each material, such as its chemical composition, physical properties and potential for reuse or recycling. Companies can then use this information to determine the most appropriate recovery type for each material, which can help improve the efficiency and effectiveness of the recycling process.

4. Recommendations for data collection

To assess the recovery potential of recycled materials, engage with buyers of recycled materials. This allows for a better understanding of how these materials are being reprocessed or reused, which can help the recycling company optimize processes to better fit the intended purpose of reuse. By understanding the specific needs and requirements of buyers, recycling companies can tailor their processes to produce materials that are more suitable for reuse, thereby increasing the value and demand for their recycled materials.

CTI use case – ERI

ERI is the largest information technology asset disposition (ITAD) and e-waste recycler in North America. Founded in 2002, it focuses on safeguarding the people, planet and privacy through responsible data destruction and e-waste reuse and recycling. ERI has processed over 1 million metric tons of e-waste from over 1,300 clients to collect and process their e-waste and worked with 209 at least R2-certified downstream partners to recover the materials back to beneficial reuse.

The company has build a proprietary tracking system – Optech – to properly track, monitor and generate reports on all incoming and outgoing materials throughout all of ERI's facilities. Optech allows it to manage all activities with clients and partners and provides access for clients to see progress on each service. This provides primary data insights into the recovery of materials to ERI partners, which adds to insights on the % actual recovery.

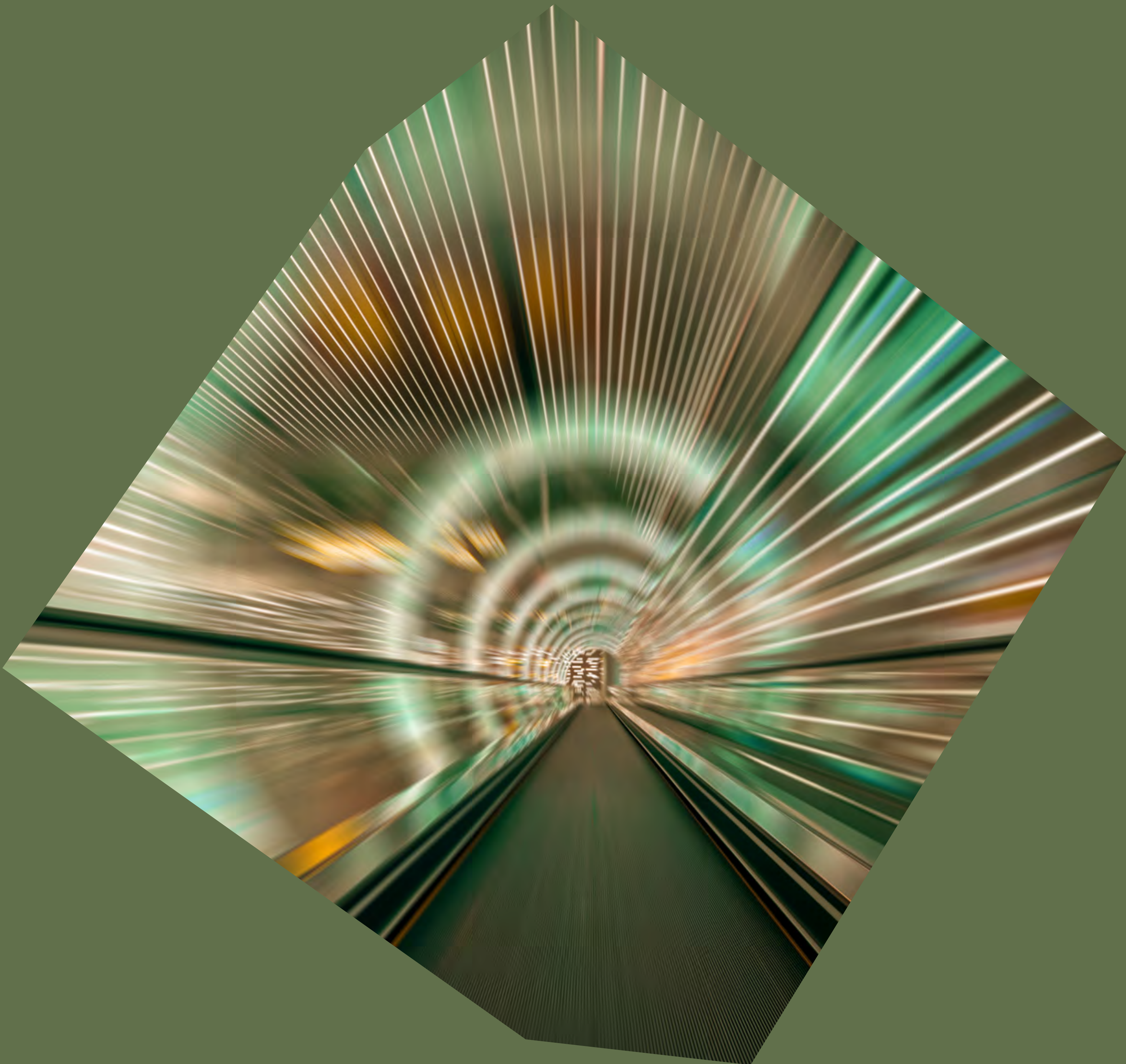
Through the proprietary tracking system, it identified more than 205 different types of incoming electronic products and generated 185 different types of commodities for reuse and recovery, with over 80,000 shipments in 2023, providing detailed insights into the material composition of electronic products as well as insights into the % recovery potential based on processing the products. The methodology helps to maintain close relationships with clients and downstream partners and can help keep the communication clear and easily identify areas for improvement.

Together with downstream partners, the compliance team works with third parties to audit partners periodically. In addition, the commodity and operations team often reviews the recycling processes to generate high-quality commodities and insights into recycled content for partners, which adds to the insights on % non-virgin inflow for partners.

Actual lifetime

The Actual lifetime indicator may not be useful for a recycling company as it primarily focuses on the lifetime of products rather than materials. Determining the lifetime of materials can be challenging, as they can potentially have a very long lifetime depending on how they are processed at the end of their use cycle. Instead, the primary focus of a recycling company is on the end-of-life stage of products, where they recover valuable materials and responsibly manage electronic waste. While promoting design for longevity and lifetime extension of products is important for overall resource efficiency, it may not align directly with the core activities of e-waste recycling.

Conclusion



04.

04. Conclusion

The electronics value chain runs on a predominantly linear economic model that is highly resource intensive and wasteful. This leads to negative environmental impacts and exposure to risks. Adopting circular business models can help the industry reduce some of these negative externalities while retaining and creating value for both users and businesses.

Several companies in the electronics value chain are at the forefront of the transition to a circular economy. Companies profiled in this guidance are setting clear circularity goals to increase the use of secondary content, including post-consumer recycled plastics. They are investing in data tracking systems to inform implementation plans, drive the company's circularity goals and develop better oversight of the chain of custody. Some of the most sophisticated technologies are using blockchain to develop "material memory". These allow material users throughout the value chain to access full material traceability, from origin to production, recycling and reuse, to better track the use of non-virgin content.

Some companies are already applying strict eco-design requirements across all new product lines. They are developing company-wide tools to build product-specific data for all materials, with a specific focus on improving recoverability and recyclability. They've started measuring revenues linked to circular products, services and solutions that contribute to circularity and responsible end-of-use management.

Many of the companies contributing to this work are piloting circular business models to improve the direct recovery of devices through take-back, trade-in, upgrade and insurance programs. Some are even piloting programs to recover older generation devices sitting idle in users' homes. To understand the impact of these programs, they are implementing systems to track recovery rates and end-of-life management, both internally and from partners, to determine the impact on circularity and waste and emissions diverted. In one of the use cases outlined in this guidance, Philips has been able to immediately see the impact of circular strategies through a 40% increase in CTI material circularity for a refurbished system compared to a new one.

Other businesses globally are building company-wide systems and roadmaps to drive, track and report increases in the use of secondary content. They are equally investing in traceability systems for end-of-life scenarios of products and striving to find ways to increase recovery so that they may capitalize on their value longer.

With such a wealth and diversity of efforts throughout the electronics value chain, a standardized measurement of success can help rally companies in the industry around common targets and objectives. Working with CTI, companies from all positions in the value chain can confidently build baselines and set targets throughout product portfolios, facilities and at the corporate level.

Well-defined performance metrics for circularity can support companies' efforts to achieve higher levels of circularity in the materials used and the design of products and business models that guarantee longer device lives and higher recovery rates, minimizing waste, pollution and risk exposure.

There is much to gain from the adoption of circular practices. We encourage companies reading this guidance to build strong corporate and performance accountability systems for circularity based on CTI so that they can measure improvements and communicate transparently with stakeholders and regulators.

WBCSD and the Circular Electronics Partnership stand ready to help companies to successfully navigate their transition to circularity.

Glossary

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

Bio-based
Wholly or partly based on biomass (based on biogenic carbon)

Chemical recycling
The process of modifying the structure of the fiber to transform it into a new fiber that can then be used.

Circular economy principles
→ 32. Design out waste and pollution

→ 33. Keep products and materials in use

→ 34. 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 (recycled, reused or remanufactured materials)

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". 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, level of degradation or, in the case of metals, degree of impurity, which leads to a loss of economic value

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 it functioning.

Emotional durability: Applying strategies that increase and maintain a product’s relevance and desirability to a user or multiple users, over time.

Physical durability: Combining material choices and garment construction, including component reinforcement, in order to create highly durable products that can resist damage and wear over long periods of time.

Electronics industry
Produces electronic equipment and consumer electronics and manufactures electrical components for a variety of products.

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

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 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 aesthetics 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.

Glossary

Land-use change
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
Inflow that is from 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 leaves no recovery potential

OR

Not demonstrably recovered nor flowing back into the economy.

Linear risk
Exposure to linear business practices: use scarce and non-renewable resources, prioritize sales of new products, fail to collaborate and fail to innovate or adapt. This will negatively impact a company's license to operate.

Mechanical recycling
Refers to the processing of fibers by sorting, grinding and compounding them for reuse.

Non-virgin inflow
Inflow previously used (secondary), e.g., recycled materials, secondhand 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).

Preparation for reuse
Refer to "recovery types"

Product lifetime
The duration of the product that starts at the moment a product is released for use after manufacturing or recovery and ends at the moment a product becomes obsolete. 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 the longer product lifetime.

Recovery
The technically feasible and economically viable recovery of compounds, materials, parts, components or even products (depending on the organization) at the same data level of functional equivalence through reuse, repair, refurbishing, repurposing, remanufacturing, recycling or biodegrading. This excludes energy recovery from waste and any biological cycle waste that does not satisfy all criteria outlined in the biological cycle.

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[42] or butterfly diagram):

- **Reuse:** To extend a product's lifetime beyond its intended 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. For the fashion industry, recycling should be separated between chemical and mechanical recycling.

Recycled
Waste material reprocessed or treated by means of production or manufacturing processes and made into a final product or a component for incorporation into a product:[43]

- Post-consumer recycled (PCR): Material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product which can no longer be used for its intended purpose.[44]
- Pre-consumer/post-industrial recycled (PIR): Material diverted from the waste stream during a manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it.[45]

Glossary

Recycling
The processing of electronic hardware products to recover usable or marketable raw materials (ingredients in manufacturing) or other products such that the original products lose their identity. Recycling does not include processing to return products to use in their original form (for example, repair, remanufacturing or refurbishing for the purpose of reusing computers).

Refurbishing
The process by which used electronic products or components are restored to a defined condition in function and form that is comparable to or better than, a new unit. The unit's composition and design does not change significantly, as in remanufacturing.[46]

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.

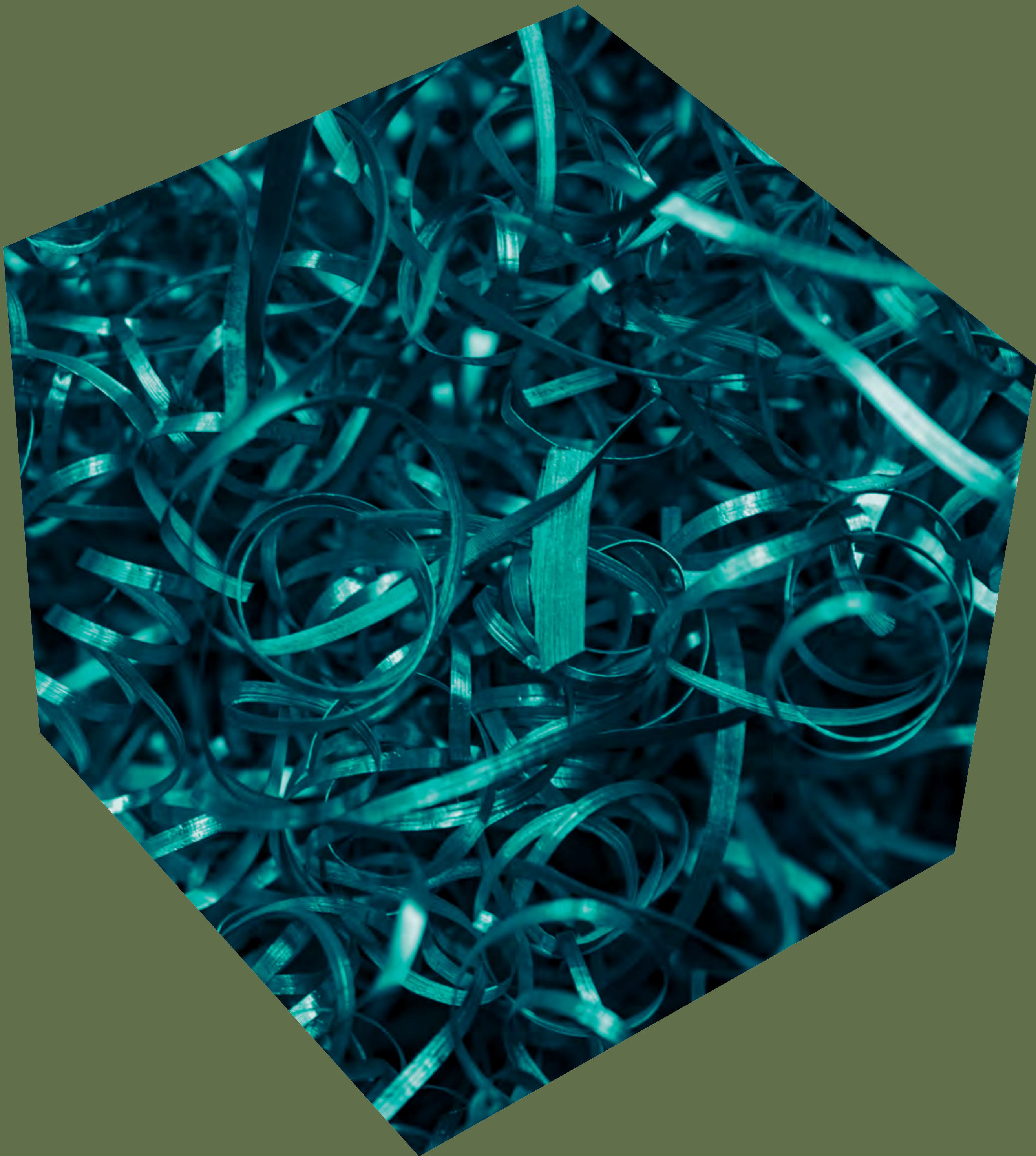
Renewable inflow
Sustainably managed resources, most often demonstrated by internationally recognized certification schemes like the Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification (PEFCRC), Roundtable on Sustainable Palm Oil (RSPO), etc. that, after extraction, 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.

Remanufacturing
All actions necessary to build up as-new products using components taken from previously used electronic equipment as well as new components, if applicable. Depending on the components used, this process may significantly change the unit's composition and design.[47]

Repair
The process by which the faults in a unit preventing its specified operation are corrected, including replacement of parts, while not significantly changing the unit's composition and design.[48]

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

Appendix



Appendix I:
Definitions of end-of-life (1/2)

	CEP	CTI	WEEE
Reuse	N.a.	To extend a product's lifetime beyond its intentional designed life span, **without changes made** to the product or its functionality	Any operation by which products or components that are not waste are used again for the **same purpose** for which they were conceived
Repair	N.a.	To extend a product's lifetime **by resorting** it after breakage or tearing without changes made to the product or its functionality	'preparing for re-use' means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be **re-used without any other pre-processing**
Remanufacture	Industrial process of **inspecting, disassembling, cleaning, reprocessing, storing, reassembling**, and **testing** an energy-related product in such a manner that the product is in a **condition equal to a newly manufactured** product or component	**To disassemble** a product to the component level and reassemble to (replacing components where necessary) **as-new condition with possible changes made to the functionality** of the product	N.a.
Refurbish	**Returning** by **industrial process** a used product to a satisfactory working condition **without making any changes** to the product	To **extend a product's lifetime** by large repair, potentially with replacement of parts, without changes made to the product's functionality	N.a.
Recycle	To reduce a product back to its material level, thereby allowing the **use of those materials in new products**	To reduce a product back to its material level, thereby allowing the **use of those materials in new products**	Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes.

Appendix I:
Definitions of end-of-life (2/2)

	ISO 59004	ISO 14021	CENELEC 45553
Reuse	Use of a product after its initial use, for the **same purpose** for which it was originally designed	A characteristic of a product or packaging that has been conceived and designed to accomplish within its life cycle a certain number of trips, rotations, or **uses for the same purpose** for which it was concei	Process by which a product or its parts, having reached the end of their first use, are used for the **same purpose** for which they were conceived
Repair	Action to **restore** a product to a condition needed for the product to function according to **its original purpose**	N.a.	Process of returning a faulty product to a condition where it ca fulfil its **intended use**
Remanufacture	**Return** an item to **original condition** from both a quality and performance perspective **using an industrial process**	N.a.	**Industrial process** which produces a product from used products or used parts where at least one change is made **which influences the safety, original performance, purpose or type of product**
Refurbish	**Restore an item**, during its expected service life, to a useful condition for the same purpose with at least similar quality and performance characteristics.	N.a.	**Industrial process** which produces a product from used products or used parts where **at least one change is made**
Recycle	**Activities to obtain recovered resources** for use in a process or a product, excluding energy recovery	**Material that has been reprocessed from recovered material** by means of a manufacturing process and made into a final product or into a component for incorporation into a product	N.a.

Appendix II:
Step 2 — selecting indicators

Manufacturing

Close the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% material circularity	Required	Required	Required
This indicator measures a company's performance in closing the loop by considering material in- and outflows, which are determined by factors such as non-virgin content, renewable content, eco-design and recovery. The material circularity indicator is a minimum requirement to complete a CTI assessment across all industries.			
% water circularity	Recommended	Recommended	Recommended
This indicator measures a company's performance in reducing freshwater demand and ensuring water resource availability for all users and the environment. Water plays a crucial role in the production process of electronic devices. A manufacturing company can enhance water circularity by evaluating and optimizing its water use. Precious metals such as rhodium, platinum, gold and palladium exhibit the highest water scarcity footprint per kilogram compared to base metals like steel, copper and aluminum.[49] Water is an essential element in the production process, particularly in instances where a company ensures the proper functioning of electronic products by using water to rinse the components, contributing to the overall water consumption. For example, it takes approximately 2,200 gallons (10,000 liters) of water, including 1,500 gallons (6,800 liters) of ultra-pure water, to create one integrated circuit on a 30-centimeter wafer. One computer can contain a multitude of those little wafers or chips.[50] By calculating water circularity, manufacturing companies can pinpoint areas where water use is most significant and explore opportunities for improvement in sustainability and resource efficiency.[51] Therefore, we recommend measuring the performance in reducing non-circular water use.			
% renewable energy	Recommended	Recommended	Recommended
This indicator measures a company's transition to renewable energy, using existing data on renewable energy consumption for business operations. The production of electronic devices is resource-intensive, requiring significant amounts of energy and water. The majority of emissions associated with electronic devices stem from the energy consumed during production processes, making energy efficiency a key concern.[52] To make this industry more sustainable, reducing emissions through clean energy use and energy conservation projects is imperative.[53] Therefore, we recommend that manufacturing companies look into how to increase the % of renewable energy.			

Manufacturing

Optimize the Loop			
Indicator	Material level	Product/component level	BU/company level
% critical material	Recommended	Recommended	Optional
This indicator measures the share of critical material inflow in a company's material flows, allowing it to assess the risk level of specific material flows and prioritize accordingly. Critical materials are materials essential to the production of electronic devices. Over one-third of materials contained in electronic products, such as smartphones and laptops, are classified as particularly critical regarding vulnerability of supply and relative economic importance of materials such as magnesium, cobalt and tungsten. The supply chains that provide critical raw materials are highly vulnerable to social, geopolitical and technical disruptions.[54] At the same time, projections show the extraction and processing of critical materials will increase rapidly, by a factor of 16, between 2020 and 2050.[55] We recommend that manufacturing companies measure the % critical materials in electronic devices because of the large dependency and the upcoming regulations regarding the use of hazardous or critical materials in electronic devices. For example, the EU has upcoming regulations: the Ecodesign for Sustainable Products Regulation (ESPR), which requires product passports including critical materials and the EU Critical Raw Materials Act (CRMA), which aims to reduce the weight of imported critical raw materials into the EU. Compliance with these regulations is crucial to avoid legal issues and penalties. Additionally, understanding the composition of devices helps manage supply chain risks. By taking a proactive approach and measuring the percentage of critical materials, companies can navigate potential challenges and ensure both legal compliance and effective supply chain management. Therefore, we recommend that a manufacturing company determine the % critical material used in its components and products.			
% recovery type	Recommended	Recommended	Recommended
This indicator measures how a company recovers outflow and recirculates it into the value chain by providing a breakdown of the recovered outflow. Manufacturing companies, especially OEMs, can have a significant influence on the actual recovery of electronic devices, for example by establishing take-back or leasing programs and engaging with end-customers to enable the collection and recovery of electronic devices or materials. By measuring the percentage of recovery type of electronic devices, a company can identify opportunities to improve its end-of-life management practices and increase the recovery and reuse of materials and components. This approach can help promote sustainability and circular economy, reduce waste and conserve natural resources. By taking a proactive approach and engaging with end-customers, manufacturers can help create a more sustainable and responsible electronics industry. Therefore, we recommend measuring the % recovery type at all levels.			
On-site water circulation	Optional	Optional	Recommended
This indicator measures how efficiently a company manages its water use. We recommend the on-site water circulation indicator at a company level rather than at a material or product level as it measures the efficiency of water use within the facility during the component manufacturing process. This indicator is relevant to assessing the overall sustainability of the company's water management practices and identifying opportunities to reduce water consumption and improve water management practices. Manufacturing companies use water, for example, in their facilities where they draw feedwater for things like cooling equipment and general purposes like maintenance and landscaping.[56] In addition, electronics facilities can also produce wastewater streams that typically need some form of treatment before they are released to the environment or to a receiving facility.[57] Therefore, we recommend evaluating on-site water circulation at the company level because manufacturing companies can increase their water circulation.			

Manufacturing

<table>
<tr><th colspan="4">Optimize the Loop</th></tr>
<tr><th>Indicator</th><th>Material level</th><th>Product/component level</th><th>BU/company level</th></tr>
<tr><td>Actual lifetime</td><td>Recommended</td><td>Recommended</td><td>Recommended</td></tr>
<tr><td colspan="4">This indicator measures a company's performance in keeping products and materials in the loop to the end of their useful lives by monitoring a product's lifetime, considering the product's technical lifetime, functional lifetime and durability.

Assessing the actual lifetime of electronic devices involves various aspects of product design, durability and circular practices. Obtaining critical data on the actual lifetime of its devices can be challenging for a manufacturing company but good insights into benchmarking actual lifetime data against industry average should be present.

If the manufacturing company has a strong collaborative relationship with downstream stakeholders involved in distribution, recycling, repairing and remanufacturing and there is a shared commitment to circular practices and product longevity, using the Actual lifetime indicator can be insightful. Therefore, we recommend assessing the actual lifetime as a manufacturing company.</td></tr>
<tr><th colspan="4">Value the Loop</th></tr>
<tr><th>Indicator</th><th>Material level</th><th>Product/component level</th><th>BU/company level</th></tr>
<tr><td>Circular material productivity</td><td>Optional</td><td>Optional</td><td>Not recommended</td></tr>
<tr><td colspan="4">This indicator illustrates the company's effectiveness in decoupling financial performance and linear resource consumption.

For a manufacturing company, various material streams for the composition of components or products exist that could be virgin and non-virgin. Therefore, it could be relevant to investigate how the non-virgin material streams impact the overall financial performance. As such, it is optional to measure this indicator at a material level, component level and product level. This guidance does not recommend using this indicator on company level since it lacks the depth needed for meaningful performance improvements.</td></tr>
<tr><td>CTI revenue</td><td>Optional</td><td>Optional</td><td>Optional</td></tr>
<tr><td colspan="4">This indicator provides a quantitative measure of a company's financial performance while accounting for the circularity of its material flows. It allows the company to assess how effectively it is generating revenue while aligning with circular economy principles.

By adjusting revenue based on the circularity of material flows, the indicator provides a more nuanced understanding of a company's financial performance. It recognizes and rewards circular practices, such as material recovery and recycling. CTI revenue serves as a quantifiable metric that can be useful in communicating to stakeholders, including customers, investors and the wider public.</td></tr>
</table>

Impact of the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
GHG impact	Recommended	Recommended	Recommended

This indicator measures a company's potential greenhouse gas emissions (GHG) savings by applying circular strategies such as the use of secondary or renewable materials as inflow and enabling recovery via higher value retention recovery, allowing companies to evaluate trade-offs and prioritize circular improvements.

The manufacturing of electronic devices is often energy-intensive and can result in significant GHG emissions. For example, making the tiny parts called integrated circuits (ICs) in electronics is a big source of GHGs. It's even more impactful than how much energy devices use, making circuit boards, creating displays and making the outer casings.[58]

Moreover, statistics show the manufacturing of a single smartphone device, including the mining of raw materials, takes as much energy as recharging and using a smartphone for 10 years.[59]

By understanding the GHG emissions associated with these processes, a company can identify areas to reduce its carbon footprint and improve its circularity. This can include optimizing energy use, reducing waste and identifying opportunities to use renewable energy sources. Additionally, assessing GHG impacts can help the company meet regulatory requirements and demonstrate its commitment to sustainability to stakeholders.

Therefore, we recommend assessing the GHG impact at the material, component, product, business unit or company level.

Nature impact	Optional	Optional	Optional

This indicator measures a company's impact on nature by screening the land-use impacts of the current material inflow and potential improvement by shifting to circular sourcing, focusing specifically on the impact from land-use change and considering the extent, condition and significance of the land used.

The electronics industry significantly impacts the environment throughout its life cycle and manufacturing companies play a crucial role in this process. Manufacturing companies can influence various stages in the life cycle, including raw material extraction, components manufacturing processes, product manufacturing processes and the disposal of electronic waste.

There are several ways the manufacturing company can reduce its impact on nature. For instance, a significant environmental impact is the consumption of natural resources. If a manufacturing company decides to decrease the use of new components in its products, the amount of non-virgin natural resources will decrease, potentially having a significant impact on the environment.

Distribution and retail

<table>
<tr><th colspan="4">Close the Loop</th></tr>
<tr><th>Indicator</th><th>Material level</th><th>Product/component level</th><th>BU/company level</th></tr>
<tr><td>% material circularity</td><td>Required</td><td>Required</td><td>Required</td></tr>
<tr><td colspan="4">This indicator measures a company's performance in closing the loop by considering material in- and outflows, which are determined by factors such as non-virgin content, renewable content, eco-design and recovery.

The material circularity indicator is a minimum requirement to a a CTI assessment across all industries.</td></tr>
<tr><td>% water circularity</td><td>Optional</td><td>Optional/ Recommended</td><td>Optional</td></tr>
<tr><td colspan="4">This indicator measures a company's performance in reducing freshwater demand and ensuring water resource availability for all users and the environment.

A retail company can measure water circularity for two areas:

→ Water use in shops that sell electronic devices;
→ Water use of electronic devices that are sold.

Water use in shops (optional)

Retail companies can assess the percentage of circularity of their shops as they are often a key sales channel for their operations. This assessment can help identify areas to reduce water consumption, improve water efficiency and implement circular water management practices. For a company selling electronic devices, the water circularity of retail shops may be less directly relevant than other sustainability metrics. Therefore, this guidance proposes this indicator as optional.

Water use of electronic devices (recommended)

A retail company can choose to assess the water impact of the electronic devices it sells as they often require significant amounts of water in its manufacturing processes and can also contribute to water pollution and waste if not properly managed at the end of their useful life. KPMG team please addres.[60]

We recommend measuring the water circularity of electronic devices at the product level for retailers, even if they are not primarily involved in the manufacturing process, because it contributes to a better understanding of the environmental impact of these products and helps identify opportunities to improve sustainability and circularity. Retailers can work with suppliers to reduce water use in the manufacturing process, promote responsible disposal and recycling of electronic devices or develop new products that are more water-efficient and sustainable. By taking these steps, retailers can help promote sustainability and circular economy and reduce the environmental impact of electronic devices.</td></tr>
<tr><td>% renewable energy</td><td>Recommended</td><td>Recommended</td><td>Recommended</td></tr>
<tr><td colspan="4">This indicator measures a company's transition to renewable energy, using existing data on renewable energy consumption for business operations.

A retail company can measure the share of renewable energy for the following areas:

→ Direct retail operations
→ Warehousing and distribution of electronic devices
→ Retail store operations, including lighting, heating and cooling
→ Corporate offices and headquarters
→ Manufacturing and production of electronic devices

Direct retail operations (recommended)

Assessing the energy consumption and share of renewable energy of processes directly related to a retail company's operations can help identify areas where the company can increase its use of renewable energy sources, such as solar or wind power and reduce its reliance on non-renewable energy sources, such as fossil fuels while reducing its carbon footprint and improve its sustainability performance.

Manufacturing and production of electronic devices (optional)

Electronic devices often require significant amounts of energy in their manufacturing processes. The production of electronic devices is resource-intensive, using energy and water to create the device. The electronic industry is responsible for 4% of global GHG emissions in 2021.[61] These emissions stem primarily from energy consumed during the product manufacturing process.[62]

By measuring the % renewable energy used in the production of electronic devices, a retailer can gain a better understanding of the environmental impact of these products and identify opportunities to improve their sustainability and circularity. This may involve working with suppliers to increase the use of renewable energy in the manufacturing process, promoting the use of energy-efficient devices or developing new products powered by renewable energy sources.</td></tr>
</table>

Distribution and retail

Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% critical material	Recommended	Recommended	Optional
This indicator measures the share of critical material inflow in a company's material flows, allowing them to assess the risk level of specific material flows and prioritize accordingly. Critical materials are materials that are essential for the production of electronic devices but that are also rare or difficult to obtain. Over one-third of materials contained in electronic products, such as smartphones and laptops, are classified as particularly critical regarding vulnerability of supply and relative economic importance of materials such as magnesium, cobalt and tungsten.[63, 64] We recommend measuring the % critical materials in electronic devices for a retailer because many countries have regulations regarding the use of hazardous or critical materials in electronic devices. For example, the EU has implemented regulations such as the Ecodesign for Sustainable Products Regulation (ESPR), which requires product passports that include critical materials and the EU Critical Raw Materials act, which aims to reduce the weight of imported critical raw materials into the EU. Compliance with these regulations is crucial to avoid legal issues and penalties. Additionally, understanding the composition of devices helps manage supply chain risks, as critical materials can be subject to disruptions. By taking a proactive approach and measuring the percentage of critical materials, companies can navigate potential challenges and ensure both legal compliance and effective supply chain management.			
% recovery type	Recommended	Recommended	Recommended
This indicator measures how a company recovers outflow and recirculates it into the value chain by providing a breakdown of the recovered outflow. Manufacturing companies, especially OEMs, can have a significant influence on the actual recovery of electronic devices, for example by establishing take-back or leasing programs and engaging with end-customers to enable the collection and recovery of electronic devices or materials. By measuring the percentage of recovery type of electronic devices, a company can identify opportunities to improve its end-of-life management practices and increase the recovery and reuse of materials and components. This approach can help promote sustainability and circular economy, reduce waste and conserve natural resources. By taking a proactive approach and engaging with end-customers, manufacturers can help create a more sustainable and responsible electronics industry. Therefore, we recommend measuring the % recovery type at all levels.			
On-site water circulation	Optional	Optional	Recommended
This indicator expresses the number of times the company uses the average drop of water on-site before it leaves the facility as outflow. On-site water circulation is an important aspect of sustainability and circular economy but it is typically more relevant to companies that have manufacturing or production facilities where water is used in the production process. If the retailer has control over the end-of-life management of the electronic devices, especially related to recycling programs, measuring the on-site water circulation of these devices may be relevant. This is because the recycling process may involve the use of water and measuring the on-site water circulation can help identify opportunities to reduce water use and improve the sustainability of the recycling process. For further guidance on how to assess the circularity of services like repair, remanufacturing and refurbishing see the section on Prepare for reuse. For further guidance on how to assess the circularity of recycling activities, see the section on Recycling.			

Distribution and retail

Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Actual lifetime	Recommended	Recommended	Recommended

This indicator measures a company's performance in keeping products and materials in the loop to the end of their useful lives by monitoring a product's lifetime considering the product's technical lifetime, functional lifetime and durability.

By measuring the actual lifetime of the devices, a retailer can assess its performance in keeping products and materials in the loop to the end of their useful lives. This can help the company identify areas for improvement and take steps to reduce waste and improve sustainability. Additionally, measuring the actual lifetime of the devices can help the company provide better information to customers about the expected lifespan of the products they are purchasing.

Assessing the Actual lifetime indicator involves various aspects of product design, durability and circular end-of-use or end-of-life practices. Obtaining critical data related to these aspects requires close collaboration with upstream suppliers and manufacturers of electronics devices and downstream partners or waste handlers.

Value the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Circular material productivity	Not recommended	Not recommended	Not recommended

This indicator illustrates the company's effectiveness in decoupling financial performance and linear resource consumption.

A retail company typically has little direct influence on the material composition, such as linear versus circular materials, of the electronic devices it sells. As a result, this indicator may provide limited insights for a retail company.

CTI revenue	Recommended	Recommended	Recommended

This indicator provides a quantitative measure of a company's financial performance while accounting for the circularity of its material flows. It allows the company to assess how effectively it is generating revenue while aligning with circular economy principles.

By measuring the CTI revenue, the company can assess how effectively it is generating revenue while aligning with circular economy principles. This can help the company identify areas where it can improve its circularity and increase profitability.

Additionally, measuring this indicator can help the company communicate its circular economy performance in relation to revenue generated to stakeholders and customers, which can enhance its reputation and competitiveness.

Distribution and retail

Impact of the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
GHG impact	Recommended	Recommended	Recommended

This indicator measures a company's potential greenhouse gas emissions savings by applying circular strategies such as the use of secondary or renewable materials as inflow and enabling recovery via higher value retention recovery, allowing companies to evaluate trade-offs and prioritize circular improvements.

This indicator measures a company's potential greenhouse gas emissions savings by applying circular strategies such as the use of secondary or renewable materials as inflow and enabling recovery via higher value retention recovery, allowing companies to evaluate trade-offs and prioritize circular improvements.

For a company that distributes and sells electronic devices, it's important to note that these devices usually contribute significantly to scope 3 GHG emissions due to the energy-intensive production process. According to research published for the 2020 IEEE International Symposium on High-Performance Computer Architecture, hardware manufacturing is the dominant source of carbon emissions throughout the life cycle of electronic devices.[65] Further statistics show the manufacturing of a single smartphone device, including the mining of raw materials, takes as much energy as recharging and using a smartphone for 10 years.[66]

By understanding the GHG emissions associated with the process, the company can identify areas to potentially reduce its carbon footprint and improve its circularity. One way to achieve this is by working with suppliers to encourage sustainable practices, such as using renewable energy sources, reducing waste and improving energy efficiency. Additionally, retail companies can promote energy-efficient products to their customers, which can help reduce demand for energy-intensive products and encourage manufacturers to produce more sustainable products. Additionally, assessing GHG impacts can help the company meet regulatory requirements and demonstrate its commitment to sustainability to stakeholders.

Indicator	Material level	Product/component level	BU/company level
Nature impact	Optional	Optional	Optional

This indicator measures a company's impact on nature by screening the land-use impacts of its current material inflow and potential improvement by shifting to circular sourcing, focusing specifically on the impact from land-use change and considering the extent, condition and significance of the land used.

Throughout the product life cycle, electronic devices have a significant environmental impact, primarily caused by the manufacturing process but also associated with the end-of-life (EoL) disposal of these devices. For example, complex electronics can contain up to 60 different elements.[67] The extraction of these minerals takes place worldwide but it's not just their finite nature that raises concerns. Mining processes are often associated with environmental challenges, including negative impacts on biodiversity, soil quality and water toxicity. Over 61.3 million tons of e-waste was generated globally in 2023 and projections show this number will reach 74 million tons in 2030.[68] E-waste contains toxic metals and chemicals that are not biodegradable and can accumulate in the environment over a long period.[69]

While a retail company may have limited impact on the manufacturing process of electronic devices it can potentially play a crucial role in reducing e-waste and its associated environmental impacts by implementing take-back and reuse programs for electronic devices. Therefore, even though a retail company may have less impact compared to manufacturing processes, it can still choose to analyze the environmental impact of electronic devices on a material and product level, particularly associated with the EoL of these devices.

Use

<table>
<tr><th colspan="4">Close the Loop</th></tr>
<tr><th>Indicator</th><th>Material level</th><th>Product/component level</th><th>BU/company level</th></tr>
<tr><td>% material circularity</td><td>Required</td><td>Required</td><td>Required</td></tr>
<tr><td colspan="4">This indicator measures a company's performance in closing the loop by considering material in- and outflows, which are determined by factors such as non-virgin content, renewable content, eco-design and recovery.

The material circularity indicator is a minimum requirement to complete a CTI assessment across all industries.

The level of assessment, whether on a business unit or company level, depends on the user's preferences and assessment goals.</td></tr>
<tr><td>% water circularity</td><td>Optional</td><td>Optional/ Recommended</td><td>Optional</td></tr>
<tr><td colspan="4">This indicator measures a company's performance in reducing freshwater demand and ensuring water resource availability for all users and the environment.

A company or individual that uses the product can measure water circularity based on the water use during the use phase of the electronic device.

A user of a device may opt for an assessment of the water impact of the electronic device during its use phase. It may seem that measuring water circularity might not be relevant as electronics generally do not involve substantial water use in operations. Depending on the scope or company boundaries, water circularity could be an interesting indicator.

The circularity impact of individual devices like laptops or phones may be minimal. In scenarios where significant water interaction occurs, such as washing machines or the cooling systems of servers, the water use can be substantial and thereby circular water use can be relevant.

Measuring the water circularity of electronic devices can be interesting for companies even if they are not primarily involved in the manufacturing process because it contributes to a better understanding of the impact of these products and help identify opportunities to improve water-use efficiency. Users of the device can work with suppliers to reduce water use in the manufacturing process, promote the responsible disposal and recycling of electronic devices or develop new products that are more water-efficient and sustainable. By taking these steps, retailers can help promote sustainability and circular economy and reduce the environmental impact of electronic devices.</td></tr>
<tr><td>% renewable energy</td><td>Optional</td><td>Recommended</td><td>Recommended</td></tr>
<tr><td colspan="4">This indicator measures a company's transition to renewable energy, using existing data on renewable energy consumption for business operations.

Measuring the share of renewable energy during the operation of an electronic device is crucial, as the use-phase often accounts for a significant portion of its total energy consumption. This can include simple day-to-day activities, such as charging a laptop or a phone, to more intensive uses like a constantly running medical apparatus or servers that operate continually. For example, the average annual power of a server may be around 1,800 to 1,900 kWh.[70]

We recommend assessing the energy consumption and share of renewable energy of processes directly related to the use of the device, as measuring the renewable energy consumption of devices while in use is crucial for improving energy efficiency. This can help identify areas where the company can increase its use of renewable energy sources, such as solar or wind power and reduce its reliance on non-renewable energy sources, such as fossil fuels while reducing its carbon footprint and improve its sustainability performance.

By understanding the energy demand of electronic devices in use and working to increase the share of renewable energy supplies, companies can fundamentally influence retailers or suppliers to strive for products that are more energy-efficient and designed with a greater emphasis on sustainability. Consequently, quantifying renewable energy use and continuously working to increase it is a valuable step in enhancing the circularity and environmental performance of electronic devices in use phase.

We recommend calculating the % renewable energy on product/component level and business unit/company level because a company can gain insights into the amount of renewable energy used when using the device. On both levels, the company can then make better decisions which device to use.</td></tr>
</table>

Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% critical material	Optional	Recommended	Optional

This indicator measures the share of critical material inflow in a company's material flows, allowing them to assess the risk level of specific material flows and prioritize accordingly.

Critical materials are essential for the production of electronic devices. Over one-third of materials contained in electronic products are classified as particularly critical regarding vulnerability of supply and relative economic importance of materials such as magnesium, cobalt and tungsten.[71, 72]

Measuring the % critical materials at a material level is optional for a company to understand the critical materials used in the device. Yet it is key to grasping the dependency risks and making informed decisions when buying a device for use.

On a product or component level, we recommend measuring the % critical material because the information can help when choosing between product options and the sum of all critical materials in devices will determine the total dependency on business unit or company level.

On a business unit or company level, we recommend measuring the % critical materials because it helps to understand the overall critical material dependency across all devices used in the operations.

Indicator	Material level	Product/component level	BU/company level
% recovery type	Recommended	Recommended	Recommended

This indicator measures how a company recovers outflow and recirculates it into the value chain by providing a breakdown of the recovered outflow.

This indicator measures how a company recovers outflow and recirculates it into the value chain by providing a breakdown of the recovered outflow.

This indicator helps to evaluate how a user contributes to the recovery and recirculation of (part of) electronic devices in the value chain. One significant factor within the recovery portion of the use phase is the preparation for reuse, which can include aspects such as repair, refurbishment and remanufacturing. The decision to extend the life of a device greatly influences the end-of-life trajectory and has a considerable impact on the recovery rate.

An item that the user decides to repair or refurbish leads to an effective extension of its lifespan, thereby augmenting material circularity and reducing waste. The determination to reappraise and potentially extend the life of products in their possession can have a profound effect on the overall recovery rate and significantly influence the actual recovery of electronic devices.

By measuring the percentage of recovery type of the electronic device, a company can identify opportunities to improve end-to-life management practices and increase the recovery and reuse of materials, components and products. This approach can help promote sustainability and circular economy, reduce waste and conserve natural resources. By taking a proactive approach in recovering the used devices, companies can help create a more sustainable and responsible electronics industry.

A company measuring the % recovery type could become an important source of information on the recovery of products for other partners in the value chain such as the OEM or retailers.

Therefore, at a material level we recommend that companies know the recovery potential of the materials in the devices which can guide decisions on repair and end-of-life management. This insight could also be a valuable data point to OEMs and recyclers.

Additionally, on a product/component level, we recommend calculating the % recovery type to understand the recovery options for each device. This can inform decisions about repair, reuse or recycling. This data can also help the company to push for better design or end-of-life strategies for OEM or other manufacturing companies.

On a business unit/company level, we recommend calculating the % recovery type because it can monitor the overall recovery rates across all devices in the company. With this information, a company can target improvement strategies, highlight sustainability credentials and share valuable data with other partners in the value chain. In this way, the company can stimulate the manufacturing of devices with a higher value of recovery by, for example, collaboration with repair partners.

Use

<table>
<tr><th colspan="4">Optimize the Loop</th></tr>
<tr><th>Indicator</th><th>Material level</th><th>Product/component level</th><th>BU/company level</th></tr>
<tr><td>On-site water circulation</td><td>Optional</td><td>Optional</td><td>Optional</td></tr>
<tr><td colspan="4">This indicator expresses the number of times the company uses the average drop of water on-site before it leaves the facility as outflow.

On-site water circulation is an important aspect of sustainability and circular economy but it is typically more relevant to companies that have manufacturing or production facilities using water in the production process.

One example of on-site water circulation could be the use of circular water in data center cooling. Companies could be interested in calculating the on-site water circulation performance when having a water recovery process in place, actively focusing on reducing water consumption.</td></tr>
<tr><td>Actual lifetime</td><td>Recommended</td><td>Recommended</td><td>Recommended</td></tr>
<tr><td colspan="4">This indicator measures a company's performance in keeping products and materials in the loop to the end of their useful lives by monitoring a product's lifetime considering the product's technical lifetime, functional lifetime and durability.

By measuring the actual lifetime of the devices, a company can assess its performance by keeping products and materials in the loop to the end of their useful lives. This can help the company identify areas for improvement and take steps to reduce waste and improve sustainability. Additionally, measuring the actual lifetime of the devices can help the company provide better information to suppliers about the expected lifespan of the products they are manufacturing.

At a material level, it is optional to calculate the actual lifetime since it is not directly relevant.

Additionally, on a product and component level, we recommend calculating the actual lifetime because understanding this for each device enables better planning of device replacements and maintenance. This data could also feed back into the value chain, informing suppliers about device longevity.

Moreover, on a business unit and company level, we recommend calculating the actual lifetime because in this way a company is able to monitor the lifespan of the devices throughout the company. This can play a big role in strategy, financial planning and sustainability efforts. This data is also valuable for both internal use and sharing with other stakeholders in the value chain.

Assessing the Actual lifetime indicator involves various aspects of product design, durability and circular end-of-use or end-of-life practices. Obtaining critical data related to these aspects requires close collaboration with upstream suppliers and manufacturers of electronics devices and downstream partners or waste handlers.

By measuring the actual lifetime, a company gains insights into the performance and sustainability of the devices they use and adds value to the total information available in the circular transition. It can influence the entire life cycle, from design and manufacturing to end-of-life management.</td></tr>
</table>

Value the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Circular material productivity	Not recommended	Not recommended	Not recommended
This indicator illustrates the company's effectiveness in decoupling financial performance and linear resource consumption. A company typically has little direct influence on the material composition, such as linear versus circular materials, of the electronic devices it sells. As a result, this indicator may provide limited insights for a user.			
CTI revenue	Recommended	Recommended	Recommended
This indicator provides a quantitative measure of a company's financial performance while accounting for the circularity of its material flows. It allows the company to assess how effectively it is generating revenue while aligning with circular economy principles. A company uses the device and, therefore, does not generate revenue by using this device. Therefore, this indicator may not provide insights for a user.			

Impact of the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
GHG impact	Not recommended	Recommended	Recommended
This indicator measures a company's potential greenhouse gas emissions savings by applying circular strategies such as the use of secondary or renewable materials as inflow and enabling recovery via higher value retention recovery, allowing companies to evaluate trade-offs and prioritize circular improvements. While materials in electronic devices can have associated GHG emissions, the impact at the use-phase is marginal. Therefore, we do not recommend measuring the GHG impact at the material level. On a product and component level, it is optional to calculate the GHG impact because the cumulative impact of devices can be significant. Knowledge of potential GHG savings could influence decisions on device selection, lease versus buy, repair and end-of-life management. On a business unit and company level, we recommend calculating the overall GHG emissions related to using the devices. Having insights into the GHG impact of the devices, companies can make decisions on how to use the devices and which devices to use. This data can guide policy, inspire change in practices and influence collaboration with OEMs. It is also very important for a company to understand the GHG impact of each device being used. This could affect selection decisions and encourages companies to demand more sustainable options from retailers and OEMs. A company is reliant on information from other parties in the value chain but the information can guide more sustainable and responsible practices and decisions.			
Nature impact	Not recommended	Optional	Recommended
This indicator measures a company's impact on nature by screening the land-use impacts of its current material inflow and potential improvement by shifting to circular sourcing, focusing specifically on the impact from land-use change and considering the extent, condition and significance of the land used. A user is primarily downstream in the electronics value chain and has therefore limited influence over the material sourcing decisions. The assessment of this indicator might be better suited for players downstream in the electronics value chain who have more direct control over material extraction and cultivation. If a company has a significant impact on material selection and sourcing and it actively participates in decisions that affect land-use change, assessing the "nature impact" indicator would be pertinent. On both a product and component level, it is optional to measure the nature impact. Understanding the nature impact of each device could affect selection decisions and encourages companies to demand more sustainable options from the retailers and OEMs. Moreover, on a business unit/ company level, we recommend measuring the nature impact because this information is important in assessing the company's footprint, informing sustainability strategies and driving dialogue with suppliers and partners about improving practices. A company is reliant on information from other parties in the value chain but the information can guide more sustainable and responsible practices and decisions.			

Preparation for reuse services

Close the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% material circularity	Required	Required	Required
This indicator measures a company's performance in closing the loop by considering material in- and outflows, which are determined by factors such as non-virgin content, renewable content, eco-design and recovery. The material circularity indicator is a minimum requirement to complete a CTI assessment across all industries.			
% water circularity	Optional	Optional/ Recommended	Optional
This indicator measures a company's performance in reducing freshwater demand and ensuring water resource availability for all users and the environment. The amount of water needed for repairing, refurbishing or remanufacturing electronic devices can vary depending on the specific processes and techniques used. In general, these activities do not typically require a significant amount of water.			
% renewable energy	Optional	Recommended	Recommended
This indicator measures a company's transition to renewable energy, using existing data on renewable energy consumption for business operations. The energy requirements for repairing, refurbishing or remanufacturing electronic devices can vary depending on the specific processes and technologies involved. Generally, these activities are considered to be less energy-intensive compared to the initial manufacturing of electronic devices from raw materials. Repairing and refurbishing typically involve tasks such as disassembly, diagnosis, component replacement and testing. These processes may require energy for running diagnostic tools, testing equipment and powering various tools used in repair and refurbishment. Remanufacturing, which involves restoring used products to like-new condition, may also require energy for disassembly, cleaning, reassembly and testing. The energy requirements are generally lower compared to the energy-intensive processes involved in manufacturing electronic devices from scratch.			

Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% critical material	Recommended	Recommended	Recommended
This indicator measures the share of critical material inflow in a company's material flows, allowing them to assess the risk level of specific material flows and prioritize accordingly. Electronic devices contain various critical materials that are rare or difficult to obtain, with over one-third of materials in products such as smartphones and laptops classified as particularly critical due to their vulnerability of supply and relative economic importance, such as magnesium, cobalt and tungsten.[73, 74] For a company specializing in preparation for reuse services for electronic devices, we recommend measuring the percentage of critical materials, as many countries have regulations regarding the use of hazardous or critical materials in electronic devices. For example, the EU has implemented regulations such as the Ecodesign for Sustainable Products Regulation (ESPR), which requires product passports that include critical materials and the EU Critical Raw Materials act, which aims to reduce the weight of imported critical raw materials into the EU. Compliance with these regulations is crucial to avoid legal issues and penalties. Managing the use, replacement, sourcing and disposal of critical materials is therefore an important consideration for companies involved in repairing, refurbishing or remanufacturing electronic devices. Monitoring the number of critical materials kept in the loop due to preparation for reuse operations can contribute to a circular economy by extending the lifespan of products through repair and remanufacturing, reducing the demand for new critical materials and managing the environmental impact associated with their extraction and processing.			
% recovery type	Optional	Optional	Optional
This indicator measures how a company recovers outflow and recirculates it into the value chain by providing a breakdown of the recovered outflow. The % recovery type is always applied to the % actual recovery. For a company specializing in repair, refurbishment and remanufacturing of electronic devices, the actual recovery is always "reuse". As a result, determining the % recovery type has limited potential insights. The different recovery types could be of interest only for waste generated during the preparation for reuse activities.			

Preparation for reuse services

Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
On-site water circulation	Optional	Optional	Optional
This indicator expresses the number of times the company uses the average drop of water on-site before it leaves the facility as outflow. Measuring this indicator may not be directly relevant for a company that repairs, refurbishes or remanufactures electronic devices, as the water circularity may not be a significant factor in its operations. If the company uses water in its processes, measuring this indicator can help identify opportunities to reduce water use and improve environmental performance.			
Actual lifetime	Recommended	Recommended	Recommended
This indicator measures a company's performance in keeping products and materials in the loop to the end of their useful lives by monitoring a product's lifetime considering the product's technical lifetime, functional lifetime and durability. Measuring this indicator on a product level is highly relevant for a company that repairs, refurbishes or remanufactures electronic devices, as it directly relates to its core business of extending the lifespan of products and materials. By monitoring a product's lifetime and considering its functional lifetime, the company can assess its performance in keeping products and materials in the loop to the end of their useful lives. This can help the company identify areas for improvement in processes and develop strategies to optimize operations, reduce waste and increase the circularity of its business model. Additionally, tracking this indicator can help the company demonstrate its commitment to sustainability and circular economy principles to stakeholders such as customers, investors and regulators.			

Value the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Circular material productivity	Not recommended	Not recommended	Not recommended
This indicator illustrates the company's effectiveness in decoupling financial performance and linear resource consumption. A company that specializes in the repair, refurbishment and remanufacturing of electronic devices typically uses a lower share of linear resources in its processes compared to manufacturing companies. While it can measure how effectively they use circular materials and components to replace broken or outdated parts, this may represent a small share of the overall device, resulting in limited insights from this indicator.			
CTI revenue	Recommended	Recommended	Recommended
This indicator provides a quantitative measure of a company's financial performance while accounting for the circularity of its material flows. It allows the company to assess how effectively it is generating revenue while aligning with circular economy principles. By measuring the CTI revenue, the company can assess how effectively it is generating revenue while aligning with circular economy principles. This can help the company identify areas where it can improve its circularity and increase profitability. Additionally, since the business model of a company that specializes in repair, refurbishment and remanufacturing of electronic devices inherently aligns well with circular principles, measuring this indicator can help communicate its circular economy performance in relation to revenue generated to stakeholders and customers. This can enhance the company's reputation and competitiveness, as it demonstrates its commitment to sustainability and circular economy principles.			

Preparation for reuse services

Impact of the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
GHG impact	Optional	Optional	Optional
This indicator measures a company's potential greenhouse gas emissions savings by applying circular strategies such as the use of secondary or renewable materials as inflow and enabling recovery via higher value retention recovery, allowing companies to evaluate trade-offs and prioritize circular improvements. As the business activities of a company that repairs, refurbishes and remanufactures electronic devices are considered to be less energy-intensive compared to the initial manufacturing of electronic devices from raw materials measuring the GHG impact may not provide valuable insights. A company could measure the amount of GHG emissions saved due to repair, refurbishment or remanufacturing compared to newly manufactured electronic devices. This can demonstrate the positive environmental contribution of its business model and highlight the benefits of circular economy principles.			
Nature impact	Optional	Optional	Optional
This indicator measures a company's impact on nature by screening the land-use impacts of its current material inflow and potential improvement by shifting to circular sourcing, focusing specifically on the impact from land-use change and considering the extent, condition and significance of the land used. Throughout the product life cycle, electronic devices have a significant environmental impact, primarily caused by the manufacturing process, but also associated with the end-of-life (EoL) disposal of these devices. For example, complex electronics can contain up to 60 different elements. The extraction of these minerals takes place worldwide but it's not just their finite nature that raises concerns. Mining processes are often associated with environmental challenges, including negative impacts on biodiversity, soil quality and water toxicity. Over 50 million tons of e-waste are generated globally every year on the downstream side of the value chain and projections show this number will reach 74 million tons in 2030. E-waste contains toxic metals and chemicals that are not biodegradable and can accumulate in the environment over a long period.[76] A company that repairs, refurbishes and remanufactures electronic devices may have limited impact on the manufacturing process of newly produced electronic devices but it plays a crucial role in reducing e-waste and the demand for newly produced products. To demonstrate the positive environmental contribution of its business model and highlight the benefits of circular economy principles, a company could measure the reduction in environmental impact due to repair, refurbishment or remanufacturing compared to newly manufactured electronic devices.			

Recycling

Close the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% material circularity	Required	Required	Required
This indicator measures a company's performance in closing the loop by considering material in- and outflows, which are determined by factors such as non-virgin content, renewable content, eco-design and recovery. The material circularity indicator is a minimum requirement to complete a CTI assessment across all industries.			
% water circularity	Recommended	Recommended	Recommended
This indicator measures a company's performance in reducing freshwater demand and ensuring water resource availability for all users and the environment. Water is often used in the recycling process for electronic devices, such as during the disassembly, sorting and processing stage or in the recovery of valuable materials from electronic devices, such as metals and plastics.[77, 78] Therefore, water use and conservation is a material topic in the recycling process due to its potential for significant environmental impacts[79] and should be measured on all levels. By measuring the % water circularity, a recycling company can assess the water intensity of its recovery processes and identify opportunities to reduce its water use.			

Recycling

Close the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% renewable energy	Recommended	Recommended	Recommended

This indicator measures a company's transition to renewable energy, using existing data on renewable energy consumption for business operations.

Recycling processes for electronic devices or materials contained in electronic devices can be energy-intensive, depending on the specific process and the materials being recycled. Some electronic products and materials may require energy-intensive processes, such as those that involve shredding, sorting and smelting to recover valuable materials. For example, the recycling of printed circuit boards (PCBs) often involves a high-temperature smelting process to recover metals from the PCBs.[80]

Therefore, it is a material topic for recycling companies and should be measured at all levels, as the use of renewable energy can impact the environmental sustainability of operations and contribute to the overall circularity performance.

Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
% critical material	Recommended	Recommended	Optional

This indicator measures the share of critical material inflow in a company's material flows, allowing them to assess the risk level of specific material flows and prioritize accordingly.

Over one-third of materials contained in electronic products, such as discarded smartphones and laptops, are classified as particularly critical regarding the vulnerability of supply and relative economic importance of materials such as magnesium, cobalt and tungsten.[81, 82] By measuring the % critical material circularity, a company recycling electronics devices a recycling company can assess its ability to recover and reuse these materials, reducing its dependence on virgin materials and contributing to resource conservation efforts.

Critical materials often have high economic value. Using this indicator might provide insights into the financial performance of the recycling operations. A recycling company could develop strategies to maximize revenue by prioritizing the recovery of materials with higher market demand. Further, critical materials can be short in supply with volatile prices. Using this indicator, a recycling company can potentially better understand its exposure to these risks. For example, they may choose to invest in new technologies to allow for more efficient recovery of critical materials or develop partnerships with other companies to ensure a stable supply.

Assessing the % critical material circularity on a company level is optional, as it does not provide specific information on the recovery and reuse of critical materials at the individual product level.

% recovery type	Recommended	Recommended	Recommended

This indicator measures how a company recovers outflow and recirculates it into the value chain by providing a breakdown of the recovered outflow.

Selecting the recovery type indicator is helpful for a recycling company when conducting a circularity assessment because different types of recycling, such as mechanical or chemical, can be used to recover valuable materials from electronic devices.[83]

By identifying the most effective and efficient recycling methods, the company can improve its recycling processes and contribute to the overall circularity of the electronic devices industry.

On-site water circulation	Optional	Optional	Optional

This indicator measures how sustainable a company manages its water use.

We recommend the on-site water circulation indicator on a company level rather than on a material or product level as it measures the efficiency of water use within the facility during the recycling process.

This indicator is relevant for assessing the overall sustainability of the company's water management practices and identifying opportunities to reduce water consumption and improve water management practices.

Recycling

Optimize the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Actual lifetime	Recommended	Recommended	Recommended
This indicator measures a company's performance in keeping products and materials in the loop to the end of their useful lives by monitoring a product's lifetime considering the product's technical lifetime, functional lifetime and durability. Assessing the actual lifetime CTI indicator involves various aspects of product design, durability and circular practices. Obtaining critical data related to product design, manufacturing and distribution can be challenging for a recycling company. This data often lies with other participants in the electronics value chain, particularly those involved in the design, manufacturing or distribution phases that have a more comprehensive understanding of the entire product life cycle. If the recycling company has a strong collaborative relationship with upstream stakeholders involved in product design, manufacturing and distribution and there is a shared commitment to circular practices and product longevity, using the Actual lifetime indicator can be insightful.			

Value the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
Circular material productivity	Not recommended	Not recommended	Not recommended
This indicator illustrates the company's effectiveness in decoupling financial performance and linear resource consumption For a recycling company, the predominant inflow comprises used materials, components or products destined for reprocessing, making it inherently circular (non-virgin). Relying on the circular material productivity indicator may prove less informative, as it fails to offer actionable insights for performance enhancement. Consequently, from the perspective of a recycling company, we do not recommend using this indicator as it lacks the depth needed for meaningful performance improvement assessments.			
CTI revenue	Optional	Optional	Optional
This indicator provides a quantitative measure of a company's financial performance while accounting for the circularity of its material flows. It allows the company to assess how effectively it is generating revenue while aligning with circular economy principles. By adjusting revenue based on the circularity of material flows, the indicator provides a more nuanced understanding of a company's financial performance. It recognizes and rewards circular practices, such as material recovery and recycling, which are central to the operations of a recycling company. CTI revenue serves as a quantifiable metric that can be useful in communicating to stakeholders, including customers, investors and the wider public.			

Impact of the Loop			
Indicator	**Material level**	**Product/component level**	**BU/company level**
GHG impact	Optional	Optional	Optional
This indicator measures a company's potential GHG emissions savings by applying circular strategies such as the use of secondary or renewable materials as inflow and enabling recovery via higher value retention recovery, allowing companies to evaluate trade-offs and prioritize circular improvement. Recycling electronic products and components to recover valuable materials can be energy-intensive, as it may require heating materials to 1.200°C for 12 hours to separate components.[84] By understanding the GHG emissions associated with the process, the company can identify areas to reduce its carbon footprint and improve its circularity. This can include optimizing energy use, reducing waste and identifying opportunities to use renewable energy sources. Additionally, assessing GHG impacts can help the company meet regulatory requirements and demonstrate its commitment to sustainability to stakeholders.			
Nature impact	Optional	Optional	Optional
This indicator measures a company's impact on nature by screening the land-use impacts of its current material inflow and potential improvement by shifting to circular sourcing, focusing specifically on the impact from land-use change and considering the extent, condition and significance of the land used. Usually, a recycling company's role is primarily downstream in the electronics value chain and it has limited influence over material sourcing decisions, the assessment of this indicator might be better suited for players upstream in the electronics value chain who have more direct control over material extraction and cultivation. If the company has a significant impact on material selection and sourcing and it actively participates in decisions that affect land-use change, assessing the "nature impact" indicator would be pertinent. A recycling company can indirectly measure its nature impact by considering the assumption that the recovery of materials reduces the extraction of virgin materials. The logic behind this approach is that recycling and reusing materials decreases demand for new raw materials, potentially mitigating the environmental impact associated with extraction and land-use change. While this indirect measurement approach is useful, it's important to note that it may not capture all aspects of nature impact, especially those related to specific land-use changes. Collaborative efforts with upstream partners in the electronics value chain, as well as engagement in initiatives promoting sustainable material sourcing, can provide a more holistic understanding of the recycling company's indirect impact on nature.			

Appendix III:
Detailed explanation of the specific indicators (1/4)

Close the Loop
% material circularity
Circular inflow

How circular are the resources, materials, products and parts sourced? Circular inflow is split into two types of inflow: renewable and non-virgin inflow. Both need analysis to determine the circular inflow. In some cases, inflow can be both renewable and non-virgin: think of recycled packaging originating from renewable sources. In such cases, only count the inflow in one type of circular inflow (renewable or non-virgin) to prevent double counting.

Renewable inflow

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.
Renewable inflow refers to sustainably managed resources originating from bio-based sources and returning to their previous stock levels through natural growth or replenishment processes at a rate faster than they are harvested or extracted. **Metals or minerals cannot be classified as renewable** since they are not bio-based and are finite resources that are extracted from the earth and cannot be replenished at a rate faster than they are consumed. Examples of renewable materials are biomaterials like silk, gums, resins, paper, wood, cardboard etc.

Non-virgin inflow

In theory, the non-virgin inflow can be classified as "non-renewable non-virgin", which refers to non-bio-based or non-biodegradable materials, components or products that are being reused or "renewable non-virgin", which refers to bio-based or biodegradable materials, components or products that are reused and therefore non-virgin. This section exclusively refers to non-renewable non-virgin flows.
Non-virgin inflow refers to previously used (secondary) materials, components or products, such as recycled materials, second-hand products or refurbished parts. Materials entering the component manufacturing facility, not originally part of the component, should be processed at the material level (e.g., solvents, acids or other chemicals).

Companies specializing in repairing, refurbishing or remanufacturing electronic devices typically process devices that have been used previously, resulting in a high share of non-virgin inflow. Consider the specifications of materials or components added during the preparation for reuse phase to replace broken parts. These materials or components may be circular (e.g., recycled materials, reused components) or linear.

Recycling processes for electronic devices or materials contained in electronic devices can be energy-intensive, depending on the specific process and the materials being recycled. Some electronic products and materials may require energy-intensive processes, such as those that involve shredding, sorting and smelting to recover valuable materials. For example, the recycling of printed circuit boards (PCBs) often involves a high-temperature smelting process to recover metals from the PCBs.[74]

Therefore, it is a material topic for recycling companies and should be measured at all levels, as the use of renewable energy can impact the environmental sustainability of operations and contribute to the overall circularity performance.

Appendix III:
Detailed explanation of the specific indicators 2/4)

Close the Loop
% material circularity
Circular outflow

Circular outflow is determined by multiplying the % recovery potential and % actual recovery of product, components and materials.

Recovery potential

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

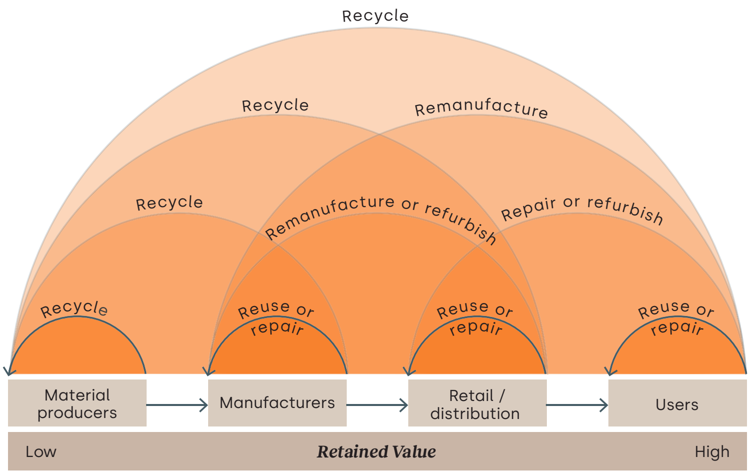
On a material or component or product level **the % recovery potential depends on its composition or assembly**. Some materials or components or products may be easier to recover than others and some have limited potential for recovery due to contamination or degradation. Components and products designed with circular principles in mind are usually easier to recover, for example through:

- → **Modular design –** Components or products designed with modularity in mind allow individual parts to be easily replaced or repaired, reducing the need to dispose of an entire device if only one part is faulty.
- → **Standardized components –** Using standardized parts ensures that replacements are easily available, facilitating repair work and reducing the dependence on specialized knowledge or unique tools.
- → **Easy disassembly** – Components or products designed for easy disassembly enable quicker and more convenient access to internal parts, reducing the time and cost associated with repairs and promoting reusability of individual parts.
- → **Durability –** Focusing on durability during the design and production phases leads to components or products that offer long-lasting performance and can endure longer periods of use without the need for frequent repairs or replacements.
- → **Upgradeability –** Designing components or products to be easily upgradable extends the lifespan of devices and reduces the need for full replacements, thus contributing to reducing electronic waste and the environmental footprint.

Actual recovery

How much of the outflow does the company actually recover?
The outflow includes products, components and waste streams. Companies can improve the actual recovery rates through closed loop business models such as take-back initiatives or mandatory or voluntary open loop recovery schemes efforts.

CTI considers the following recovery types:



Appendix III:
Detailed explanation of the specific indicators (3/4)

Optimize the Loop
% critical material inflow

Critical materials are materials prone to becoming scarce in the relatively near future and are difficult to substitute without hampering functionality. Several institutions have identified critical raw materials. The EU, for example, identified 34 raw materials in 2023.[85]

A company can define critical materials by considering a variety of factors, such as the **importance of the material to the company's operations**, the **availability and accessibility of the material** and the **potential environmental and social impacts** associated with the material's extraction and use.

We recommend first **referring to existing** definitions and classifications or critical materials, such as those developed by the European Union or the United States. These definitions typically consider factors such as the economic importance of the material, the risks associated with its supply and its importance to emerging technologies.

To determine the importance of certain materials to a company's operations, companies can consider the following factors:

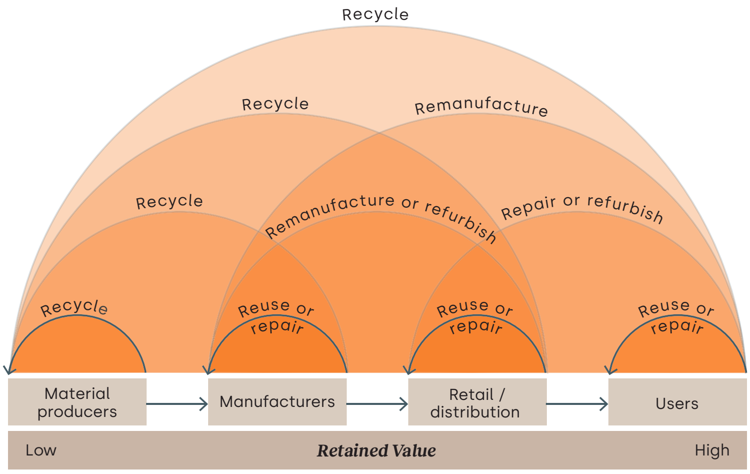
- → Quantity: How much of the material does the company use in its products or processes? Is the material a major component or a minor one?
- → Functionality: What is the role of the material in the company's products or processes? Is it essential or can the company substitute it with another material?
- → Availability: Is the material readily available or is it subject to supply chain risks, such as geopolitical instability or resource depletion?
- → Cost: What is the cost of the material? Is it a significant expense for the company?

Environmental and social impacts: What are the environmental and social impacts associated with the extraction, production and disposal of the material? Are there any risks or negative impacts that the company needs to consider.

Recovery type

For the Optimize the Loop module, the % recovery type provides a deep exploration of higher value retention strategies within company reach; % recovery type is applied to % actual recovery.

Recovery type is applied to % actual recovery. CTI considers the following recovery types:



Electronic devices can be subject to various recovery types depending on their condition at the time of take-back and the suitability of their design for different recovery methods. For instance, devices that are mainly glued together instead of screwed can be more difficult to repair or remanufacture and are more likely to end up in material recycling processes. This highlights the importance of designing electronic devices with circular economy principles in mind, such as modularity and ease of disassembly, to facilitate repair, reuse and refurbishing.

Appendix III:
Detailed explanation of the specific indicators (4/4)

Optimize the Loop
Actual lifetime
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. 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".[86] This definition is in line with CSRD's reporting requirements for design for durability among other circular principles. Implementing strategies to extend the lifetime of products once they become obsolete leads to higher circularity and value retention. Specifically, extending product lifetime can minimize the need to buy additional products and thus reduce resource use and waste creation. **Emotional durability:** The Ellen MacArthur Foundation has defined emotional durability as a strategy to "increase and maintain a product's relevance and desirability to a user or multiple users, over time." Understanding and engaging with consumers and creating a sense of product desirability can improve the way the consumer uses the product and for how long. This aspect is particularly relevant for the electronics industry as trends and desirability define many products. Additionally, trends encourage the production and consumption of items that may only be desirable for a single season. Producing classic and timeless products could also increase their emotional durability. **Physical durability:** A product's physical durability is a strategy for combining materials and constructing them to create durable products that can resist damage and wear. Designing for durability is a core circular design principle to improve the physical durability of products. The regular use of textiles means the company can shift some attention to the choice of material, composition and construction of the item to extend its lifetime. When considering the actual lifetime of a material, consider the durability of the material and its ability to be recycled. The durability of a material refers to its ability to maintain its properties and functionality over time, even when subjected to wear and tear or exposure to environmental factors. Materials that are more durable are likely to have a longer lifetime and be more suitable for recycling. Additionally, the ability of a material to be recycled can also impact its lifetime. Materials that are easily recyclable and reusable are more likely to have a longer lifetime and contribute to a more circular economy. On the other hand, materials that are difficult to recycle or have limited end-of-life options may have a shorter lifetime and contribute to waste. The recycling process can impact the quality and properties of the recycled material, which can in turn affect its durability and potential for reuse. For example, if a material is recycled using a process that degrades its properties or introduces impurities, the resulting recycled material may have a shorter lifetime and be less suitable for reuse. On the other hand, if a material is recycled using a process that maintains or improves its properties, the resulting recycled material may have a longer lifetime and be more suitable for reuse.

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Disclaimer

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Attribution

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About the Circular Transition Indicators

In recent years, the circular economy has increasingly appeared as the new model to pursue sustainable economic growth. Companies require consistent measurement processes and metrics to assess their circular performance. To address this need, we have worked with our members and stakeholders to jointly develop a universal framework to measure circularity. The Circular Transition Indicators (CTI) is a transparent, objective and evolving framework that is applicable to businesses of all industries, sizes, value chain positions and geographies.

About the WBCSD

The World Business Council for Sustainable Development (WBCSD) is a global community of over 225 of the world's leading businesses driving systems transformation for a better world in which 9+ billion people can live well, within planetary boundaries, by mid-century. Together, we transform the systems we work in to limit the impact of the climate crisis, restore nature and tackle inequality.

We accelerate value chain transformation across key sectors and reshape the financial system to reward sustainable leadership and action through a lower cost of capital. Through the exchange of best practices, improving performance, accessing education, forming partnerships, and shaping the policy agenda, we drive progress in businesses and sharpen the accountability of their performance.

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