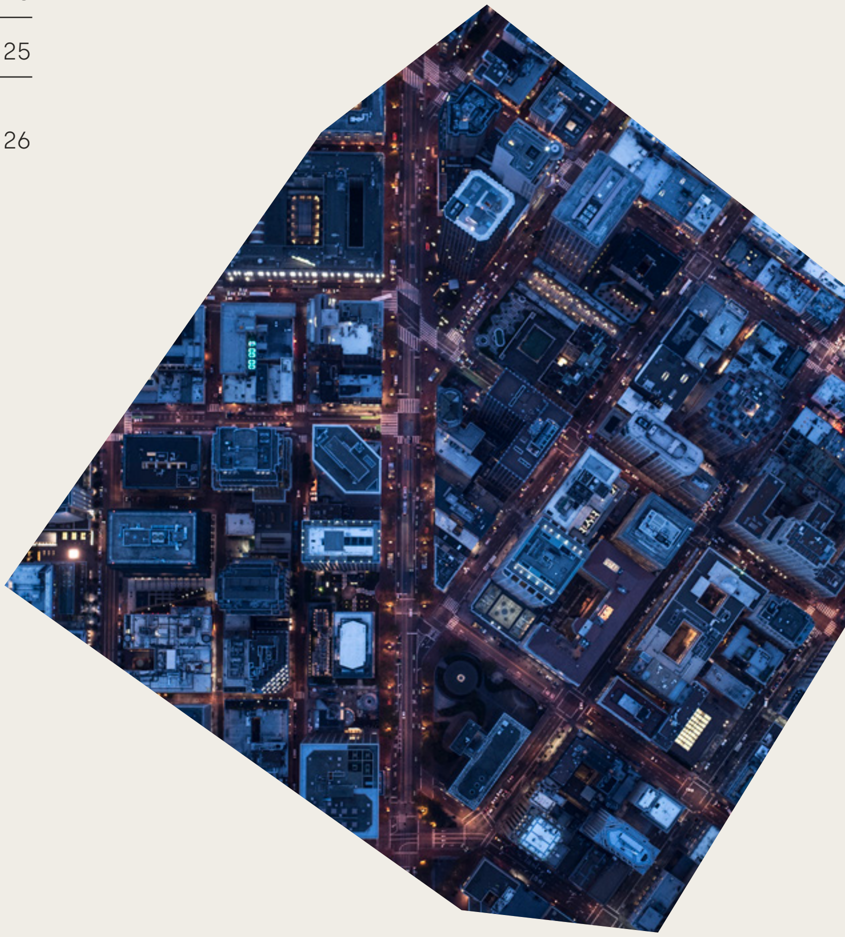
Circular Transition Indicators (CTI)

→ *Sector Guidance - Buildings*

World Business Council for Sustainable Development

Contents



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We developed this guide in close consultation with a broad range of stakeholders, find a full list here.

Foreword

Foreword

Buildings and infrastructure shape how we live, work and connect with the world around us. The built environment underpins economic development and societal well-being, yet its predominantly linear model – defined by resource extraction, energy-intensive processes and short-term design – is placing unsustainable pressure on our planet and the systems we depend on.

The sector is at a critical inflection point. It is responsible for nearly 40% of global carbon emissions and over a third of global resource consumption. Construction and demolition alone generate an estimated 1.4 billion metric tons of waste annually, much of which companies landfill or downcycle – leading to environmental degradation, lost material value, rising costs and growing systemic risk.

The circular economy offers a powerful response. Circular strategies – such as designing for longevity and adaptability, enabling reuse and refurbishment, and leveraging digital tools like material passports – can significantly reduce embodied carbon while unlocking economic opportunity. Evidence suggests circular construction can cut emissions by up to 38% while reducing dependency on virgin materials and increasing operational efficiency. Importantly, circularity also strengthens business resilience, supports regulatory readiness and creates long-term competitive advantage in an increasingly resource- and carbon-constrained world.

Market dynamics are accelerating this shift. Regulatory frameworks such as the Corporate Sustainability Reporting Directive (CSRD), extended producer responsibility (EPR) schemes, digital product passports (DPP) and embodied carbon regulations are reshaping expectations. At the same time, innovation in design, materials and digital platforms is making circularity more scalable than ever.

To support this transition, the World Business Council for Sustainable Development (WBCSD), working with its members and partners, has developed the **Circular Transition Indicators (CTI) for Buildings**. Based on CTI v4.0, this guidance offers practical metrics and definitions for assessing and improving circular performance across the building life-cycle – empowering organizations to reduce impact, boost efficiency and future-proof their portfolios.

The Circular Transition Indicators (CTI) provide the methodological foundation for performance measurement and management within the Global Circularity Protocol for Business led by WBCSD and One Planet Network (hosted by UNEP) —a unified global framework for setting targets, measuring outcomes, and reporting progress on resource efficiency and circularity.

We invite all stakeholders to adopt CTI as the shared language for circular action. Together, we can create a built environment that is not only low-carbon and resource-efficient, but regenerative, inclusive and economically resilient.

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Executive summary

01.

01. Executive Summary

The built environment is one of the largest contributors to global environmental challenges. It is responsible for nearly 40% of global CO_2 emissions, with material extraction, production and disposal driving resource depletion at an unsustainable rate. Buildings account for 50% of global material use, yet only 10% of materials re-enter the economy after demolition. The sector follows a linear model, leading to excessive waste and inefficiencies. At the same time, regulatory pressures, investor expectations and market demand for sustainable and circular business models are accelerating. Stricter environmental, social and governance (ESG) regulations and increasing demand for transparent sustainability reporting require companies to demonstrate circularity efforts.

Despite growing awareness, measuring and managing circular performance remains a major challenge. Many organizations lack standardized metrics, struggle with end-of-life material reuse, and face uncertainty in regulatory compliance. This guidance introduces a new building life-cycle-based methodology, the Circular Transition Indicators (CTI) for Buildings which is designed to address these challenges by providing a comprehensive approach to measure and manage circular performance in buildings. Following the CTI core methodology (v4.0), CTI for Buildings helps companies in the built environment sector understand and improve the circular performance of their buildings and projects. It also supports internal decision-making and initiates value chain collaboration and discussions.

The methodology introduces a holistic assessment framework that measures circular performance at five critical stages of a building's life-cycle:

- **Design:** Ensuring buildings are designed for adaptability, disassembly and material recovery.
- **Construction:** Optimizing material use, construction waste and emissions reductions.
- **Operation:** Achieving extended lifespan and energy efficiency.
- **Retrofitting:** Enhancing durability, minimizing environmental impact, preserving the building's value and ensuring compliance with new regulations.
- **Deconstruction:** Enabling closed loops by ensuring efficient material recovery and re-integration and the minimization of waste and greenhouse gas (GHG) emissions.

Adopting a life-cycle-based methodology for measuring and managing circular performance, such as the CTI for Buildings, will help companies set circularity roadmaps and measurable targets, track progress on sustainability goals and enhance regulatory compliance. This will ensure alignment with evolving frameworks such as the Corporate Sustainability Reporting Directive (CSRD), the EU taxonomy, ESG reporting standards, and circular economy policies and regulations. Additionally, the integration of circularity principles into each stage of a building's life-cycle projects can lead to emissions reductions of up to 38% and related cost savings.[1] It can also boost investor confidence and offer a competitive advantage.

We invite all stakeholders in the built environment value chain to adopt CTI as their preferred framework for measuring and managing their circular performance. By speaking a common language and adopting a unified way to measure success, the sector can successfully transition to a more resource-efficient, low-carbon and regenerative built environment – one where materials retain their highest value, there is minimal waste, and every stage of a building's life-cycle embeds sustainability.

Introduction

02.

02. Introduction

The built environment encompasses the human-made spaces designed to support activities, ranging from individual buildings and parks to neighborhoods, cities and their associated infrastructure – such as water supply systems and energy and digital networks. It represents a material, spatial and cultural outcome of human effort, combining physical and intangible networks that facilitate living, working and recreation.[2] With the global urban population expected to rise from 55% today to almost 70% by 2050,[3] the demand for urban infrastructure will skyrocket, with projections currently estimating an increase of 241 billion m^2 of new floor area by 2060 compared to 2020 levels.[4] With such a significant influence, building sustainably by applying circular economy principles is essential in driving the systemic and transformative change needed to accelerate decarbonization and sustainable development.

However, the sector faces persistent challenges, including resource depletion, excessive waste generation and high carbon footprints, as buildings represent around 40% of total global carbon emissions, 50% of global material extraction, 33% of global water consumption and 35% of global waste generation.[5] Traditional linear practices – characterized by a "take, make, waste" approach – dominate construction and deconstruction processes, leading to inefficiency and environmental degradation.[6] Additionally, the evolving, highly complex and resource-intensive sustainability regulation requirements, such as the Corporate Sustainability Reporting Directive (CSRD), make it difficult for companies to keep up with compliance, adding to the increasing sustainability-related costs.[7]

A circular economy is an economic model that is regenerative by design, aiming to preserve the value of products, components and materials by fostering innovative business models that promote durability, optimal reuse, refurbishment, remanufacturing and recycling. By adopting circular economy strategies, companies can collaborate to eliminate waste, enhance resource efficiency, remain within planetary boundaries and unlock economic benefits.[8] The adoption of circular economy principles in the built environment can present an innovative and impactful solution to these challenges by focusing on resource efficiency, material recovery, adaptability and longevity from the design phase and across the life-cycle stages of buildings.

By applying circular economy strategies, the built environment sector has the potential to reduce the global carbon emissions from building materials by 38%[9] and, according to a study published by the World Economic Forum and McKinsey, 75% of the sector's embodied carbon emissions by 2050, abating 3.4 to 4 Gt CO_2.[10] Additionally, the same study mentions that embedding circular economy practices in the built environment sector has the potential to yield an annual profit gain of USD $31-46 billion by 2030 and USD $234-360 billion by 2050. More specifically, projections show the estimated annual net value impact of recirculating materials and minerals will reach USD $31-48 billion by 2030 and USD $184-310 billion by 2050. Meanwhile, the net impact of reuse and remanufacturing will range between USD $6-13 billion in 2030 and USD $45-96 billion by 2050.[11]

As the link between circular economy strategies and decarbonization efforts becomes increasingly tangible, the financial sector has turned its focus to embedding circularity efforts in their climate transition plans.[12] As banks move from setting greenhouse gas (GHG) emissions reduction targets to implementing them, the need to assess their portfolios against circularity criteria and the respective climate impact becomes crucial to financial decision-making. By investing in circular solutions and projects while reducing financing for high-GHG-emitting activities, financial institutions can lower their financed emissions and support emissions reductions through transition finance. This approach also helps them progress toward their own climate change mitigation targets.[13] Hence, businesses from the built environment sector that adopt circular practices and communicate their circular performance could benefit from this transition by leveraging sustainability-linked financing, preferential loan terms that stem from circularity actions and the attraction of impact-oriented investments.

A clear method for assessing the implementation of circular principles in buildings is key to evaluating circular resource use and performance evaluation. Establishing a consistent measurement framework and adopting a standardized approach can enable stakeholders to evaluate the circularity of their buildings and identify steps to enhance their performance, ultimately driving the transition to a more sustainable built environment.[14] To address this gap, we propose the WBCSD Circular Transition Indicators (CTI) framework.

The Circular Transition Indicators

As the circular economy gains traction, preparing for the transition towards a more circular business model and associated risks and opportunities is essential for companies. To enable this transition, WBCSD, along with 50+ member companies, has developed the Circular Transition Indicators (CTI), a quantitative and objective framework that guides companies in measuring the circular performance of products or business processes. It helps companies identify the solutions that will have the greatest impact on their business, evaluate and understand those risks and comprehend the impact of their circularity strategies and actions.[15]

CTI has proven applicable across industries and value chains. It offers a simple methodology that is scalable and flexible in scope. It helps companies assess their circular performance at different business levels, such as the product level, the business unit level or the full company. The design of the methodology is sector-, geography- and material-agnostic. It provides four indicator modules (Figure 1).[16]

Figure 1: The four indicator modules of the CTI methodology[17]

1 *Close the Loop*
- → % material circularity
- → % water circularity
- → renewable energy

2 *Optimize the Loop*
- → % critical material
- → % recovery type
- → actual lifetime
- → onsite water circulation

3 *Value the Loop*
- → circular material productivity
- → CTI revenue

4 *Impact of the Loop*
- → GHG impact
- → nature impact
- → social impact

The CTI methodology includes a 7-step process cycle (Figure 2) that aims to guide companies through their circularity performance assessment journey and provide them with the necessary information to improve it and support further decision-making and emerging reporting requirements.[18]

The process starts with the identification of the objectives and the scope of the assessment in terms of the business level, the period and which material flows the company will include in the assessment.

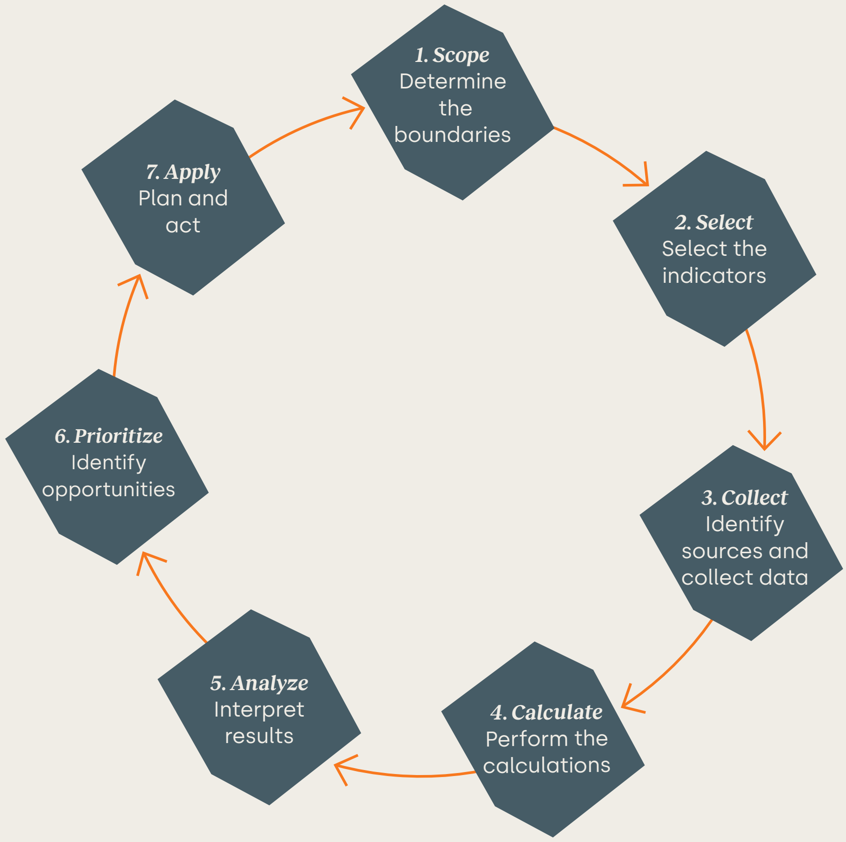
Afterwards, the company determines the set of indicators that are in scope for the assessment. It should choose the indicators based on the scope of the assessment and the additional insights the company wants to gain from the assessment.

The next steps are to collect the necessary data and perform the calculations. Based on an analysis of the results, the company drafts an action roadmap to advance circularity and prioritize key actions. The prioritization can be performed by identifying risks and opportunities that arise from adopting circular practices, through a scenario analysis exercise. The 7th step is to develop an action plan, including SMART (Specific, Measurable, Achievable, Relevant and Time-Bound) targets and initiatives, that will focus on the prioritized roadmaps.[19]

A collaborative effort between WBCSD, partners and member organizations was behind the development of the built environment sectoral guidance. The CTI for Buildings methodology provides a standardized framework to measure circularity in buildings and steer the industry towards a shared vision of a sustainable and low-carbon built environment. Additionally, the methodology supports companies with data-driven decision-making for a more circular business model and compliance with emerging reporting requirements by facilitating transparent communication, comparability and regulatory risk mitigation. It encourages the transition towards a low-carbon construction sector by:

- Promoting low-carbon, recycled or renewable materials that require less energy for extraction and processing;
- Supporting circular design and construction methods that reduce material waste;
- Ensuring the easy upgrading, deconstruction and repurposing of building components, minimizing deconstruction activities that produce waste and GHG emissions;
- Encouraging retrofitting instead of demolition;
- Promoting closed material loops that reduce the need for new material extraction;
- Encouraging on-site reuse of materials.

Figure 2: The seven step CTI process[20]



CTI for Buildings: *Methodological approach*

03.

03. CTI for Buildings: *Methodological approach*

Introduction

Circular Transition Indicators for Buildings is WBCSD's fourth sectoral guidance, after the Fashion and Textiles, Chemicals and Electronics sectoral guides. The work on CTI for Buildings began in 2022 with a landscape analysis of the metrics required to assess circularity in buildings. The **Measuring circular buildings – key considerations** white paper, published in 2023, includes an initial analysis of how to measure circularity in the built environment, along with an alignment exercise with CTI core methodology. **The business case for circular buildings: Exploring the economic, environmental and social value** white paper, published in 2021, explores the business case for circular buildings, including an economic, environmental and social perspective and case studies from the Netherlands, Denmark and the UK.

We based the indicators and approach recommended in this guidance on consultations and the testing of an extensive list of metrics (qualitative and quantitative) to measure material flow and circularity in buildings. Thirty companies were involved in testing the feasibility and strength of the metrics and the impact of the methodology in driving decision-making throughout 2024.

The methodology follows the CTI 7-step process, starting with setting the objectives and ending with the establishment of SMART targets and action roadmaps to increase the circular performance of buildings and the company itself. Along with CTI's core indicators, the CTI for Buildings methodology includes 23 additional indicators and is adapted to support the calculation of a building's circular performance across the life-cycle stages of a building (see Annex – List of Indicators).

To efficiently capture a building's circular performance at the desired level of granularity, we've based the methodology on the stages of a building's life-cycle and the inclusion of the building's layers. The methodology recommends performing the CTI assessment at every stage of a building's lifetime, using recommended indicators for each stage. This approach differentiates from the one in the CTI core methodology (product focus) by accommodating for a building's life-cycle, which can last more than 60 years, with the possible application of different conditions from its design to its deconstruction stage. For example, during design, the material recovery rates of a specific region might be lower than the deconstruction stage due to the introduction of new recovery infrastructure. The approach allows communication, knowledge exchange and benchmarking between companies that lead each stage, as rarely there is only one company managing the same building in every life-cycle stage.

Figure 3: The life-cycle stages of a building

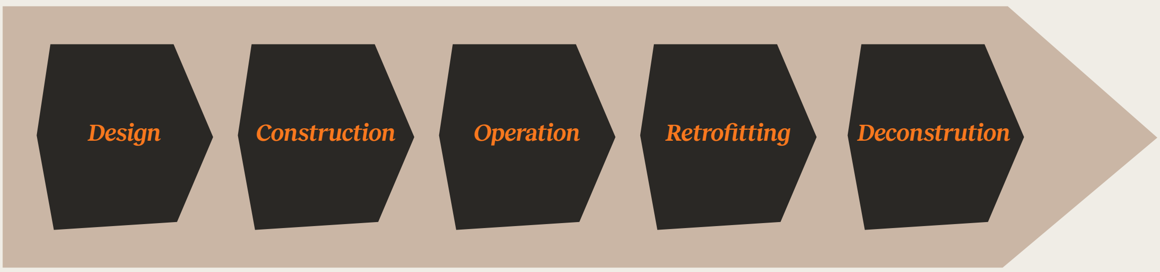


Table 1 provides an overview of the indicators per stage.

Table 1: Overview of indicators according to the building's life-cycle stage

Design	*Construction*	*Operation*	*Retrofitting*	*Deconstruction*
Material flow	**Material flow**	**Material flow**	**Material flow**	**Material flow**
→ % material circularity → Circular inflow ◦ Renewable inflow ◦ Secondary inflow ◦ Recycled inflow → Total inflow → Circular outflow ◦ % actual recovery ◦ % recovery potential (see Circular Design) → Total outflow	→ % material circularity → Circular inflow ◦ Renewable inflow ◦ Secondary inflow ◦ Recycled inflow → Total inflow → Circular outflow ◦ % actual recovery ◦ % recovery potential ◦ Construction waste → Total outflow	→ % material circularity → Circular inflow ◦ Renewable inflow ◦ Secondary inflow ◦ Recycled inflow → Total inflow → Circular outflow ◦ % actual recovery ◦ % recovery potential ◦ Operational waste → Total outflow	→ % material circularity → Circular inflow ◦ Renewable inflow ◦ Secondary inflow ◦ Recycled inflow → Total inflow → Circular outflow ◦ % actual recovery ◦ % recovery potential ◦ Construction waste → Total outflow	→ % material circularity → Circular inflow → Total inflow → Circular outflow ◦ % actual recovery ◦ % recovery potential ◦ Demolition waste → Total outflow
Circular design	**GHG performance**	**Circular design**	**Circular design**	**Circular design**
→ Adaptable building → Expansion → Adaptable floor area → Component disassembly (qual.) → Component disassembly (quant.) → Material passport → Reuse plan → Multi-use space (qual.) → Multi-use space (quant.) → Design for robustness → Lifespan (qual.) → Lifespan (quant.) → Retrofit → Material flow analysis → Modularity (qual.) → Modularity (quant.) → Refuse new construction → Refuse unnecessary components → Flexibility	→ Carbon intensity	→ Lifespan	→ Adaptable building → Adaptable floor area → Component disassembly (qual.) → Component disassembly (quant.) → Material passport → Reuse plan → Lifespan → Material flow analysis → Modularity (qual.) → Modularity (quant.) → Refuse new construction → Refuse unnecessary components	→ Actual lifespan
			GHG performance	**GHG performance**
			→ Carbon intensity	→ Carbon intensity

The life-cycle of a building

As a building goes through multiple stages during its life-cycle, understanding them is crucial to promoting circular practices, ensuring the minimization of resource extraction and climate- and nature-negative impacts. We provide a short description of each stage and how the circular focus changes in each of them:

1. **Design:** The design stage sets the foundation for a building's development, delving into the materials, resources and principles that the building's construction will follow. At this stage, circular strategies such as design for disassembly, use of non-virgin materials and design for longevity will ensure the high recoverability of building components, the minimization of virgin materials and long-lasting structures that companies can repurpose.

2. **Construction:** In the construction stage, the company translates the design plans into a physical structure on-site. Circular strategies discussed and applied in the design stage should follow the development of the building in the construction stage. Digital tools like building information modelling (BIM), material passports and digital twins can enhance resource efficiency, data collection and traceability.

3. **Operation:** After construction, the building enters its longest stage, the operation. This stage is characterized by the use of the building from its occupants and it significantly affects water and energy consumption and waste generation. Additionally, this stage includes maintenance activities that will ensure system durability and high functionality. Introducing energy- and water-efficient systems, such as photovoltaic connections and grey water recycling, can help increase the consumption of renewable energy and minimize water use, while encouraging circular behaviors where the occupants can help reduce waste generation.

4. **Retrofitting:** As buildings need to adapt to comply with new regulations, accommodate changes in user needs or simply maintain efficiency over time, the retrofitting stage focuses on upgrading the existing building infrastructure instead of demolishing and reconstructing a new building. The retrofitting stage can come more than one time and it includes upgrades in all the building's layers. Examples may include the improvement of insulation, the integration of smart technologies and the installation of energy-efficient materials in windows and doors. Companies can also apply the circularity strategies followed in design and construction in retrofitting to increase the overall circularity of the building and its lifespan.

5. **Deconstruction:** This stage signals the building's end of life, when the building can no longer be used or altered. Applying circular practices during this stage can ensure the careful demounting, collection and reintegration of materials in new projects, minimizing waste generation and closing the material loop. Additionally, the use of low-carbon materials during the design and construction stages can reduce the negative climate impacts associated with that stage.

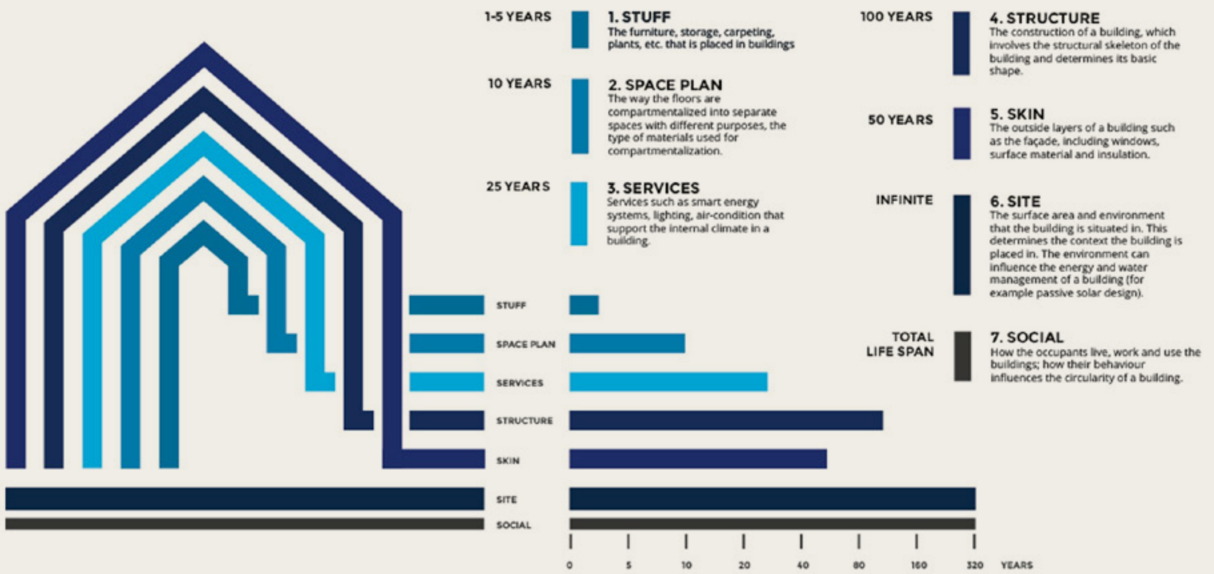
Buildings are complex systems and thus more challenging to capture in a single circularity assessment.[21] To increase the level of the assessment's granularity, we followed the Shearing Layers approach. Architect Frank Duffy first coined the concept in 1992 and Stewart Brand developed it further in his 1994 book How Buildings Learn: What happens After They're Built.[22] The Shearing Layers concept simplifies the whole building into six layers, namely the site, the skin, the structure, the services, the space plan and the stuff. Definitions of each layer are below:[23, 24]

- **Site:** The legally defined location within the urban environment where the building is constructed;
- **Skin:** Exterior surfaces (including walls, windows and doors);
- **Structure:** The sub- and super-structure (including the foundation, the frame, upper floors, roof, stairs and ramps and retaining walls);
- **Services:** Wiring (electrical and communications), plumbing, fire sprinkler systems, heating, ventilation and air conditioning (HVAC) and moving parts (elevators);
- **Space plan:** The interior layout of the building (internal walls and doors, floor and ceiling finishes);
- **Stuff:** Furniture and equipment.

A seventh layer (Social), added at a later stage, covers the behavioral aspect of a building's use, as the activities embedded in different social and cultural contexts[25] can affect the circularity of a building. For example, if future buyers and tenants prefer virgin materials, then the developers will avoid using non-virgin content when designing and constructing the building. Figure 4 presents the seven layers.[26]

The CTI for Buildings methodology v1.0 focuses on assessment across four out of seven layers: **skin, structure, services** and **space plan**, along with an **extra layer that captures the circularity of the whole building**. We chose this approach to give users the flexibility to perform the assessment to the level of detail they find most useful. Additionally, we decided to exclude the site, the stuff and the social dimension layers to avoid overcomplication of the first version of the guidance. Based on user feedback, future methodological updates may explore the inclusion of additional layers.

Figure 4: Brand's Shearing Layers[27]



Note: As lifespan varies based on usage, geographical region and environmental conditions, the number of years mentioned in the figure is a reference value.

Target audience

The built environment system is a fragmented yet interconnected and diverse value chain that includes different stakeholder groups, such as construction companies, manufacturers, users, real estate agents and financial services, who collaborate to deliver buildings.[33] The different stakeholder groups are in three distinct levels in the value chain: the companies, the sectors and the segments.[34]

Companies: The individual entities that provide services to building projects based on the specific line of business they belong to (for example design companies).

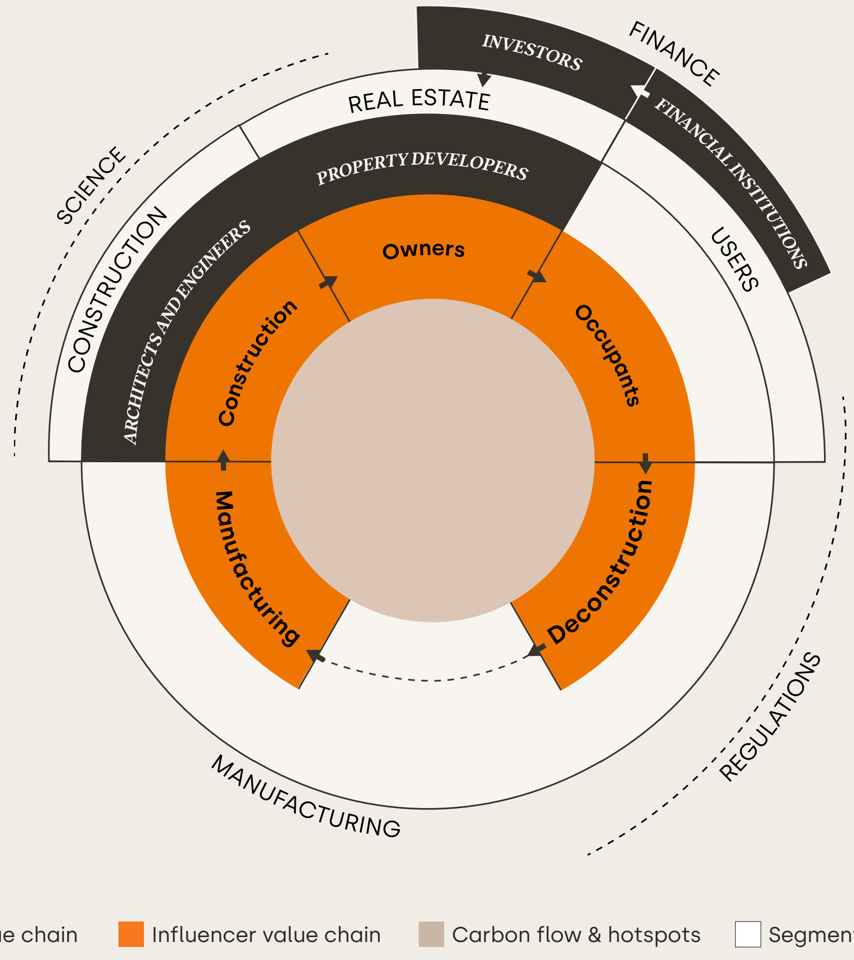
Sectors: The traditional way of grouping companies that belong to the same sector (for example, material sectors such as steel manufacturers or concrete manufacturers).

Segments: Companies from different sectors of the value chain that collaborate based on specific roles and characteristics.[35]

- Manufacturers provide the building equipment, such as materials, construction equipment and elements;
- Construction companies include designers, architects and engineers and are responsible for the creation of the building;
- The real estate segment consists of asset owners, property developers, brokers and facility managers and has an ownership or transactional relationship with the building;
- Users include the final occupiers of the building (such as residents, office space workers);
- Finance is responsible for the mobilization of the building's capital and consists of financial institutions, investors and insurance companies.

Sectors from the same segment have similar objectives and functions. Figure 5 provides a graphical representation of the built environment value chain.

Figure 5: The built environment value chain[36]



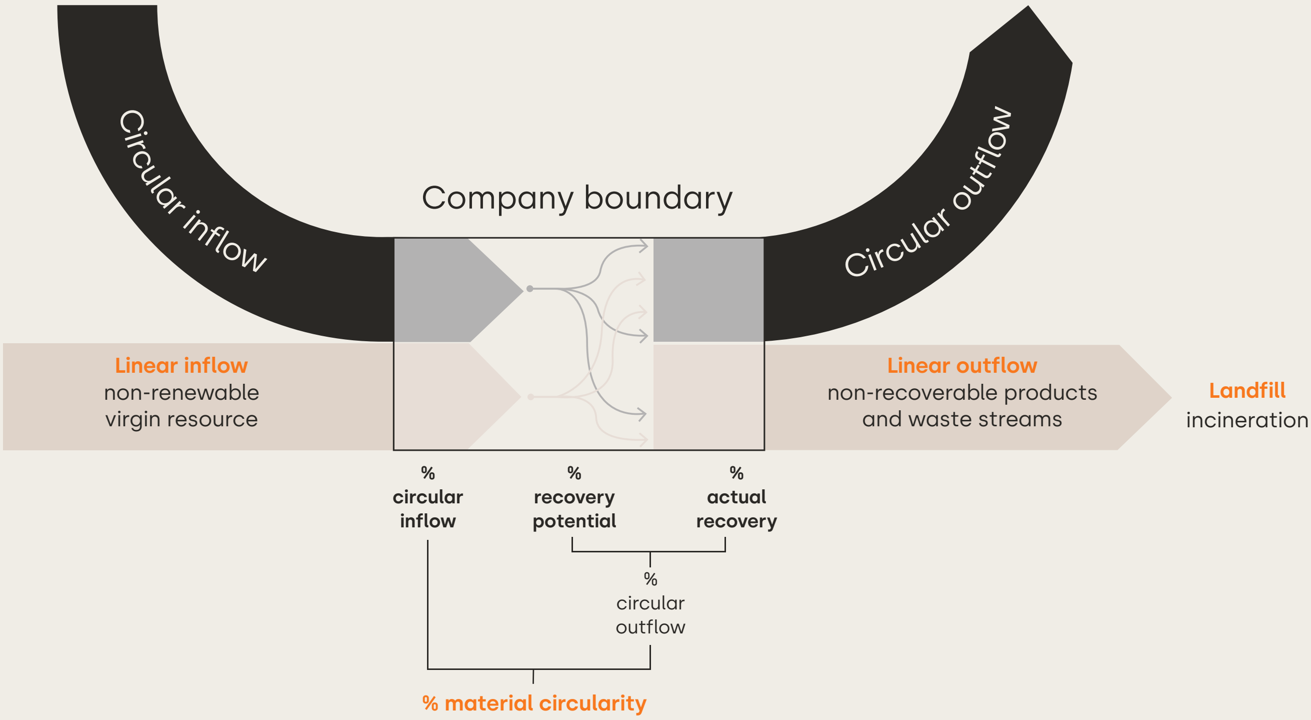
CTI for Buildings methodology

In CTI for Buildings, the assessing company calculates a circularity score (% material circularity indicator) at each stage of a building's life-cycle, considering indicators for material flow in the building and the adoption of circular design principles. This circularity score represents the company's performance for the project under scope and the project's circular performance for that life-cycle stage. To calculate the % material circularity, companies need to gather data on their circular performance at three key intervention points (Figure 6):

- **The material inflow:** Assessing how circular the materials that flow into the project are, measured by the % circular inflow indicator;
- **The design stage**: Assessing the project's potential for recovery, measured by the % recovery potential;
- **The end-of-life stage**: Assessing how much of the project's outflow it is actually possible to recover after the project's end of life, measured by % actual recovery.

After gathering the data, companies can use **Equation 1** to calculate the % material circularity, CTI's most important indicator.

Figure 6: % material circularity - methodological approach[28]



Equation 1: % material circularity

$$\frac{\text{Circular inflow (mass)} + \text{Circular outflow (mass)}}{\text{Total inflow (mass)} + \text{Total outflow (mass)}}$$

Following the CTI core methodology, the units of the material flow indicators (Table 1) in CTI for Buildings guidance are based on mass (kg). In cases where the assessing company receives the bill of materials in a different unit (such as in volume units), it can easily convert them using the following formula: Mass (kg) = Volume (m^3) x Material density (kg/m^3). This ensures consistency and comparability across all assessments, as well as with the CTI core methodology.

% circular inflow

The % circular inflow indicator shows the amount of circular content in the materials that a company procures for its project. To calculate the % circular inflow for the project, the company needs the following data points.

% circular inflow data points

- → Total inflow (kg)
- → % of recycled content (% of kg)
- → % reused content (% of kg)
- → % of renewable content (% of kg)

Types of circular inflow

Renewable

The CTI core methodology defines renewable content (inflow) as content originating from sustainably managed resources, most often demonstrated by internationally recognized certification schemes like the Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification (PEFC) or Roundtable on Sustainable Palm Oil (RSPO). After extraction, these resources return to their previous stock levels through natural growth or replenishment processes at a rate in line with use cycles. Therefore, they replenish/regrow at a faster rate than harvested/extracted.[29] This definition aligns with the one from ISO 21930 and LEED that define renewable resources as resources replenished by natural processes within a relatively short timescale without depleting the long-term resource base. Examples include FSC-certified timber, cellulose insulation created from FSC-certified recycled paper and FSC-certified wood shingles.

Reused

In the CTI context and according to LEED certification, reused inflow pertains to materials or components that are directly repurposed in new products (or buildings) without significant alteration. Specific examples from the built environment industry includes reclaimed wood, doors, windows, and fixtures that are extracted, inspected for quality, and then integrated into new structures.

Recycled

Recycled content refers to materials that have been processed from waste (altering the physical form of the material) into reusable substances that can be used for the creation of new products (or buildings). This definition aligns with ISO 14021, that defines recycled inflow as the materials diverted from waste streams during manufacturing, excluding reutilization within the same process. Examples from the built environment industry may include concrete that is crushed and used as an aggregate or metals that are melted down and reformed.

After confirming the numbers, **equation 2** shows the formula to calculate the % circular inflow:

Equation 2: % circular inflow

% recycled content + % reused content
+ % renewable content

Companies can perform the calculation of % circular inflow at all levels of granularity (see example on page 39).

% circular outflow

The % circular outflow indicator shows how efficiently a company ensures the recoverability of the materials used in the building and is the combination of % recovery potential and % actual recovery indicators. To calculate the % circular outflow for the project, the company needs the following data points:

- % recovery potential
- % actual recovery per material
- Material flow masses (kg)
- Total outflow (building or project material mass in kg)

% recovery potential

The % recovery potential arises from the company's adoption of circular design strategies, namely adaptability, demountability, utilization, longevity, material use, modularity, refusal and flexibility (See Annex - Glossary for definitions). The eight strategies pair with the respective qualitative and quantitative indicators, aiming to show how many of them the company applies during the building's design. The calculations give a single adoption percentage to each circular design strategy, which is assigned, using a combination of a "Yes or No" approach for the qualitative indicators and a range approach for the quantitative indicators. Table 2 shows the eight strategies with their respective indicators and how to calculate the adoption percentage of each strategy. As we've designed the scoring system based on specific combinations of indicators, the calculation column includes only the cases where a company can earn points on the adoption percentage of a specific circular strategy. Scenarios not listed here do not meet the required conditions for scoring.

Recovery

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

Recovery potential vs actual recovery

CTI is based on the material flows through the company and entails the assessment of the flows within the company's boundaries at three key intervention points: the procurement, design and after sales stages. The % recovery potential and the % actual recovery indicators cover the last two points and can be described as follows:

- **% recovery potential:** How does the assessing company design its products to ensure the technical recovery of components and materials at a functional equivalence (such as by designing for disassembly, repairability, recyclability or that they are biodegradable). In the built environment value chain, this question entails the adoption of circular design practices in design-related life-cycle stages.
- **% actual recovery:** How much of the outflow does the company actually recover? The term outflow includes products, by-products and waste streams and comprises all material and components recovered through all the recovery strategies (see Recovery). As the indicator depends highly on the maturity status of the market where the companies operate, companies can improve the actual recovery rates by developing closed loop business models or mandatory or voluntary open loop recovery schemes.

Table 2: Circular design strategies, indicators and calculation instructions

Strategy	*Indicators*	*Qualitative/ quantitative*	*Calculation*
Adaptability	Adaptable building	Qualitative (Y/N)	→ Two yes and more than 60% => 100% in Adaptability → One yes and 40%-60% => 50%
	Expansion	Qualitative (Y/N)	
	Adaptable floor area	Quantitative (% of m²)	
Demountability	Component disassembly	Qualitative (Y/N)	→ 1 yes and more than 60% in Quantitative => 100% in Demountability → 1 yes and 40%-60% in Quantitative => 50%
	Component disassembly	Quantitative (% of kg/m³)	
Utilization	Multi-use space	Qualitative (Y/N)	→ 1 yes and more than 60% in Quantitative => 100% in Utilization → 1 yes and between 40-60% => 50%
	Multi-use space	Quantitative (% of m²)	
Longevity	Design for robustness	Qualitative (Y/N)	→ 2 yes => 100% in Longevity
	Lifespan	Qualitative (Y/N)	→ 1 yes => 50%
Material use	Material passport	Quantitative (% of kg/m³)	→ 1 yes and more than 60% in Quantitative => 100% in Material use → 1 yes and 40-60% in Quantitative => 50%
	Reuse plan	Quantitative (% of kg/m³)	
	Material flow analysis	Qualitative (Y/N)	
Modularity	Modularity	Qualitative (Y/N)	→ 1 yes and more than 60% in Quantitative => 100% in Modularity → 1 yes and 40-60% in Quantitative => 50%
	Modularity	Quantitative (% of kg)	
Refuse	Refuse new construction	Qualitative (Y/N)	→ 2 yes => 100% in Refuse
	Refuse unnecessary components	Qualitative (Y/N)	→ 1 yes => 50%
Flexibility	Flexibility	Quantitative (% of m²)	→ >60% => 100% in Flexibility → 40-60% => 50%

While the majority of this information and data are in the assessing company's jurisdiction, complementary sources that can drive decision-making at this stage of the building's life-cycle could include design load regulations and standards and engineering or design codes (like Eurocodes). The company then aggregates the eight adoption percentages into a single percentage that forms the % recovery potential for this stage, using **Equation 3** (see example on page 28).

Equation 3: % recovery potential

$$\frac{AP_{Ad} + AP_{Dem} + AP_{Ut} + AP_{Long} + AP_{MU} + AP_{Mod} + AP_{Ref} + AP_{Fl}}{8}$$

Where:

AP_{Ad}: Adoption percentage of adaptability

AP_{Dem}: Adoption percentage of demountability

AP_{Ut}: Adoption percentage of utilization

AP_{Long}: Adoption percentage of longevity

AP_{MU}: Adoption percentage of material use

AP_{Mod}: Adoption percentage of modularity

AP_{Ref}: Adoption percentage of refusal

AP_{Fl}: Adoption percentage of flexibility

However, as there are sometimes trade-offs between these strategies (such as demountability and longevity), companies may choose to focus on some of these strategies, excluding the ones that are not relevant. In that case, Equation 3 becomes:

$$\frac{\sum \text{Adoption percentages}}{\text{Number of strategies adopted}}$$

% actual recovery

The company can calculate its % actual recovery per material by either its primary recovery data (such as records of reused materials and components) or in publicly available recovery rates by region or sector (datasets from the European Union's statistics database EUROSTAT or that of the US Environmental Protection Agency – EPA – for example). To calculate the % actual recovery for the whole project, companies need to use **Equation 4**:

Equation 4: % actual recovery

$$\frac{(\%\text{ actual recovery}_X \times \text{mass X}) + (\%\text{ actual recovery}_Y \times \text{mass Y}) + ...+ (\%\text{ actual recovery}_n \times \text{mass n})}{\text{Total outflow}}$$

In this equation, X, Y and n are all the different material outflows that together comprise the building's or project's material mass. The next step is to calculate the % circular outflow of the project using the **Equation 5** (see example on page 36).

Equation 5: % circular outflow

$$\%\text{ recovery potential} \times \%\text{ actual recovery (total)}$$

To calculate the % material circularity, companies need to calculate the mass of their circular inflow and circular outflow, which they can find by multiplying the % circular inflow and the % circular outflow indicators with the total inflow and total outflow masses respectively.

The next section provides guidance on how to calculate the circular performance of the project under scope at every intervention point for each life-cycle stage. Companies are meant to repeat the process after each life-cycle stage and, after the building's end of life (deconstruction), a final circularity score will emerge as the aggregation of the respective life-cycle stages scores, which will reflect the building's overall circular performance.

To promote building longevity through adaptability, maintenance and adaptive reuse, we propose a weighting system (longevity factor) after the building's end of life to reward buildings that extended their originally planned lifespan. The longevity factor (LF) is the ratio between the actual (deconstruction stage) lifespan and the planned lifespan (design and retrofitting stages) (**Equation 6**). Its use is as a multiplier to the building's final circularity score.

Interpretation of the LF:

- LF > 1: The building exceeded the planned lifespan
- LF = 1: The building lasted as long as expected
- LF < 1: The building was demolished/ deconstructed earlier than planned.

Equation 6: Longevity factor

$$\frac{\text{Actual building lifespan}}{\text{Planned building lifespan}}$$

Where there are multiple companies assessing the same building during its lifetime, it is necessary to establish communication channels between them to allow for lifespan data exchange to establish the potential difference in the lifespan.

However, as the built environment industry is not extensively exploring longevity due to the higher upfront costs of durable materials and heterogeneity in industrial perceptions of the future of durable buildings,[30] in this version of CTI for Buildings, the LF only strives to reward buildings that exceed their intended lifetime and not penalize buildings for early deconstruction. **Equation 7** provides the formula to calculate the building's final circularity score (see example on page 46).

Equation 7: Final circularity score

$$\frac{\%MC_{Design}+\%MC_{Construction}+\%MC_{Operation}+\%MC_{Retrofitting}+\%MC_{Deconstruction}}{5} \times LF$$

Where:

$\%MC_{stage}$: % material circularity of the respective stages

LF: Longevity factor (only when LF ≥ 1)

GHG performance

Carbon intensity is closely linked to the adoption of circular practices in buildings, as reducing embodied carbon is a key principle of circular construction. By designing for material reuse, deconstruction and resource efficiency, buildings can minimize emissions associated with material extraction, processing and disposal. Measuring carbon intensity (kg CO_2e/m^2) allows for informed decisions on material selection, reuse strategies and waste reduction and can also offer comparability insights into which interventions have the highest impact on lowering a building's carbon impact, improving future design and construction practices. A circular approach prioritizes low-carbon, durable and recyclable materials, ultimately reducing the environmental footprint of the built environment while extending the life-cycle of resources.

CTI for Buildings includes a carbon intensity indicator for the construction, retrofitting and deconstruction stages. Relevant data points for this assessment include:

- Total CO_2 emissions for the year of the assessment (kg CO_2) or for the entire duration of project in the case of retrofitting;
- Total building/project area (m^2).

The company can obtain these data points through the following data sources:

- Environmental product declarations;
- Lifecycle Assessments (LCA) databases;
- Industry tools that allow CO_2 calculations (such as One Click LCA, Athena Impact Estimator).

Note that this list is non-exhaustive and companies can obtain the data from other relevant sources.

After gathering the data, the company can use **Equation 8** to calculate the carbon intensity (see example on page 32).

Equation 8: Carbon intensity

$$\frac{\text{Total } CO_2 \text{ emissions of the building}}{\text{Total building area}}$$

Layer aggregation

When conducting the exercise on a more granular level, for example by assessing circular performance in the skin, structure, services and space plan, companies can use the following methodology to aggregate the results of the layers with the aim to create the whole building layer.

The first step is to perform the assessment for the individual layers and calculate the % material circularity indicator for each layer respectively. Then, companies should use a weighted average approach to create the % material circularity for the whole building layer. Each layer contributes differently to the overall material intensity of the building. Table 3 provides the weights of the different layers.

Finally, the last step is to calculate the % material circularity indicator using the weighted average approach (**Equation 9**):

Equation 9: The weighted average approach for layer aggregation

$$MC_B = \frac{(MC_{St} \times W_{St}) + (MC_{Sk} \times W_{Sk}) + (MC_{Ser} \times W_{Ser}) + (MC_{Sp} \times W_{Sp})}{4}$$

Where:

MC_x = % material circularity of the x layer

W_x = Weight of the x layer

B = Whole building layer

St = Structure layer

Sk = Skin layer

Ser = Services layer

Sp = Space layer

Companies can use the same methodology for individual indicators of the assessment (for example, % circular inflow or % recovery potential) if they want to get additional insights for the whole building layer.

CTI for Buildings Tool

WBCSD along with partner companies is developing an excel file to help companies complete the assessment. The tool will include:

- A separate tab for each stage of a building's lifecycle, with relevant indicators that measure the project's circular performance for that specific stage.
- An aggregation tab that brings together all the circularity scores from the different stages and produces the final circularity score for the whole building, calculating also the LF. This tab will also features visuals from each stage that reflect the project's circular performance in different categories.

For information on how to access to the tool, please send an e-mail to cti@wbcsd.org.

Table 3: Weights of the different building layers[31, 32]

Layer	*Weight*	*Justification*
Structure	40%	Highest material mass and longest lifespan
Skin	30%	Significant material mass
Services	20%	Medium material mass but frequent maintenance
Space plan	10%	Lowest material mass

Setting the objectives and scope

As a first step of the methodology, a company needs to identify the objectives and scope of the assessment. This is an important step as it allows the company to understand the reason behind the assessment and the insight that it hopes to get by performing it. A starting point to setting the objectives is the question: **What is the intent for the assessment?**

The following questions can help refine the company's objectives:

- **Why is circularity important to the company?**
- **What kind of questions would we like to answer by doing this assessment?**
- **Who is the audience of the assessment and what would we expect the audience to do with the insights of this assessment? What kind of questions do we expect them to ask after reviewing the outcomes of the assessment?**

After answering these questions and establishing the objectives, the next step is to define the scope of the assessment. Setting the scope can help the company frame its boundaries and limitations. A study conducted by WBCSD in 2022 recommends that the scope of the assessment include information on the project's geographic location, life-cycle stage, typology and year of construction.[37] These insights are crucial to the assessment's overall approach, as legislation can change based on this information. Value chain dialogue and collaboration could prove valuable at this stage, as it requires data from contractors and suppliers.

To set the scope of the assessment, companies can use the questions below where relevant:

- **Where is your project taking place/is going to take place?**
- **What resources are available in the region and what circular practices are in place?**
- **What is the year of construction?**
- **At which life-cycle stage is the project?**

  In this guidance, the building's life-cycle considers the following stages: design, construction, operation, retrofitting and deconstruction. Depending on the life-cycle stage, the circular strategies assessed could be different. For example, if a project is at the design stage, the focus of the assessment could be on the adoption of circular design practices, whereas if a project is in the construction stage, the focus can shift to material flows.

- **What kind of building is it?**

  Building typology depends on the character of the occupancy and can include residential, educational, institutional, industrial, business, retail and assembly.

Guidance by stage in the building's life-cycle

Life-cycle stage: Design

Companies in the design stage will approach a building's circularity differently than other life-cycle stakeholders. The focus of this stage is to ensure the minimization of waste and virgin resource use, durability, safe deconstruction and material recovery at the end of the building's life-cycle. By adopting circular design principles from the early design stages, buildings can significantly reduce their environmental impact and support a more regenerative economy. Table 4 presents a non-exhaustive list of companies that belong in the design stage.

Additionally, companies at this stage of a building's lifetime can perform the assessment at the building level (using the whole building layer) or at a more granular level by completing the assessment for the respective layers that their project refers to. For example, an engineering firm that designs HVAC systems can complete the assessment for the services layer and, if requested, pass the data and the results of the assessment to the company that manages the whole building's design plan to complete its own assessment.

Table 4: Non-exhaustive list of design stage companies

Company	*Role*
Architecture firms	Responsible for the conceptual approach, spatial planning and aesthetics
Engineering firms	Responsible for ensuring the building's strength and stability, designing HVAC and plumbing systems, planning site development, drainage systems and infrastructure
Interior designers	Responsible for designing layout, materials, lighting and furnishings
Building surveyors	Responsible for ensuring that buildings are safe, functional and compliant with legal and regulatory standards.
Sustainability consulting firms	Responsible for sustainability certification, eco-friendly materials and energy efficiency

Design stage indicators

Companies in the design stage can use the indicators in Table 5 to perform the CTI assessment. As mentioned above, the assessment will lead to forming the % of material circularity for the design stage.

% circular inflow

In the design stage, the **% circular inflow data points** are estimates that will drive the conversation on performance in the construction stage. After confirming the numbers, companies could use the formula described in **Equation 2**.

The company can calculate the % circular inflow at all levels of granularity based on the scope of the project.

Table 5: Indicators for the design stage

Category	*Indicators*

Material flow	**% material circularity**
	→ % circular inflow
	  ◦ Renewable inflow
	  ◦ Secondary inflow
	  ◦ Recycled inflow
	→ % circular outflow
	  ◦ % actual recovery
	  ◦ % recovery potential(*)
	→ Total inflow
	→ Total outflow

Circular Design	**% recovery potential (*)** → Adaptable building → Expansion → Adaptable floor area → Component disassembly (qual.) → Component disassembly (quant.) → Material passport → Reuse plan → Multi-use space (qual.) → Multi-use space (quant.) → Design for robustness → Lifespan (qual.) → Lifespan (quant.) → Retrofit → Material flow analysis → Modularity (qual.) → Modularity (quant.) → Refuse new construction → Refuse unnecessary components → Flexibility

% circular outflow

In the design stage, the % actual recovery and the total outflow of the building or project are, once again, estimations of the design plan that will drive the performance discussion at the construction stage. After the data collection, companies could use the formula described in **Equation 4** and **Equation 5** to calculate the % actual recovery (total) and the % circular outflow. As with the % circular inflow, the company can perform the calculation at every layer based on the scope of its project.

% recovery potential

In the design stage, the % recovery potential arises from the company's adoption of circular design strategies: adaptability, demountability, utilization, longevity, material use, modularity, refusal and flexibility. The calculation of % recovery potential uses the formula in **Equation 3.** In cases where a strategy is not relevant to a specific company's project, the company can skip the indicator and provide the necessary documentation on why the indicator is not relevant to their project. In the previous example, the engineering firm designing HVAC systems, the company can skip the adaptability and utilization strategies and calculate the % recovery potential using the rest of the six circular design strategies, adapting **Equation 3** as follows:

$$\frac{AP_{Dem} + AP_{Long} + AP_{MU} + AP_{Mod} + AP_{Ref} + AP_{Fl}}{6}$$

Example

An architecture firm has undertaken the design of a new residential building and performs the CTI for Buildings methodology to assess the circular performance of the building's design. Table 6 provides their answers and the adoption percentage for each strategy.

By aggregating the adoption percentages for all circular design strategies, the % recovery potential for their whole project is 69% (rounded). Even before the calculation of the indicator, Table 6 already shows where the company can focus to raise its score. Adopting refusal and utilization circular strategies or planning for the building's future expansion in the next project can help the company increase the % recovery potential even more.

After the calculations for % recovery potential, % circular inflow and % circular outflow are in place, the company can use Equation 1 to calculate the % material circularity.

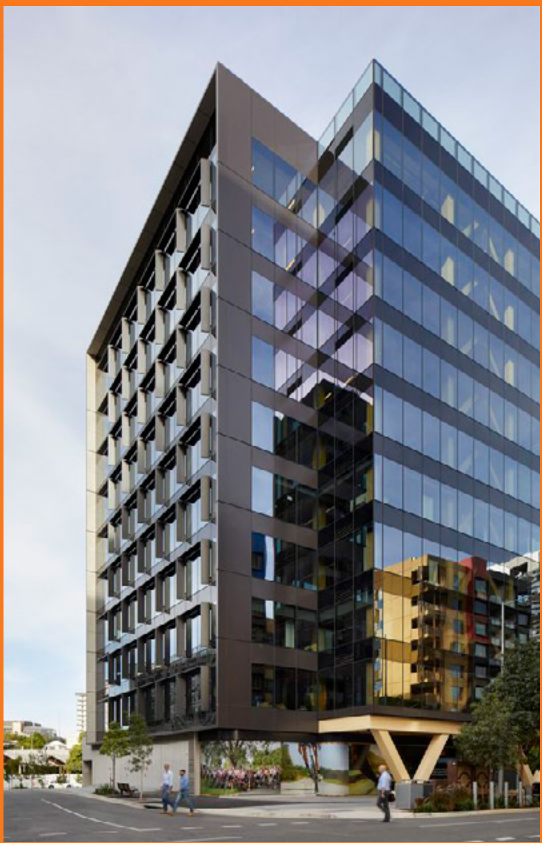
Table 6: Example of % recovery potential calculations

Category	*Indicators*	*Answer*	*% adoption*
Adaptability	Adaptable building	Yes	50%
	Expansion	No	
	Adaptable floor area	50%	
Demountability	Component disassembly	Yes	100%
	Component disassembly	65%	
Utilization	Multi-use space	No	0%
	Multi-use space	—	
Longevity	Design for robustness	Yes	100%
	Lifespan	Yes	
	Lifespan	60 years	
	Retrofit	10 years	
Material reuse	Material passport	60%	100%
	Reuse plan	75%	
	Material flow analysis	Yes	
Modularity	Modularity	Yes	100%
	Modularity	65%	
Refuse	Refuse new construction	No	0%
	Refuse unnecessary components	No	
Flexibility	Flexibility	75%	100%
% recovery potential			**69%**

Case study - 25 King Street, Brisbane[38]

25 King Street, developed by Lendlease and Floth, is a standout example of circular design in commercial architecture. As Australia's tallest timber office building, it uses cross-laminated and glue-laminated timber sourced from certified forests, significantly reducing embodied carbon and enabling carbon sequestration. The building was designed for disassembly using modular components prefabricated off-site to minimize waste and allow for future reuse. Integrated sustainability features—such as rainwater harvesting, high-efficiency HVAC, and LED lighting—contributed to its 6-Star Green Star Design & As-Built v1.1 and WELL Core and Shell Platinum certifications. This project demonstrates how thoughtful material selection, adaptable design, and efficient construction can embed circular economy principles into the built environment.

Figure 7: 25 King Street Building in Brisbane, Australia



Life-cycle stage: Construction

The construction life-cycle stage is where all the planning and design of the previous stage comes to life. The focus of this stage is to ensure sustainable material use and optimization, construction waste and emissions reductions. The adoption of circular economy strategies in the construction stage not only prevents resource depletion, landfilling and increased GHG emissions, it also enables costs savings for developers and contractors, healthier buildings and indoor environments and new business models that assist in job creation. Table 7 presents a non-exhaustive list of companies in the construction stage.

As with the design stage, companies in the construction stage can use both the whole building layer or the rest of them depending on their project and level of granularity. Material suppliers and manufacturers can also use the CTI core methodology, as it is more product-oriented than CTI for Buildings.

Construction stage indicators

Companies in the construction stage can use the indicators in Table 8 to perform the CTI assessment. As mentioned above, the assessment will lead to forming the % material circularity for the construction stage.

Table 7: Non-exhaustive list of construction stage companies.

Company	*Role*
Engineering firms	Responsible for overseeing site preparation, ensuring the project's integrity, conducting site inspections, overseeing installations, coordinating with subcontractors, providing technical guidance on logistics and ensuring compliance with regulations
General contractors	Responsible for overseeing the entire construction process, managing sub-contractors, scheduling and performing quality controls
Civil contractors	Responsible for handling site preparations, excavations, foundations and infrastructure work
Material suppliers & manufacturers	Responsible for providing building materials such as steel, concrete, insulation, wood and glass

Table 8: Construction stage indicators

Category	*Indicators*
Material flow	**% material circularity** → % circular inflow ◦ Renewable inflow ◦ Secondary inflow ◦ Recycled inflow → % circular outflow ◦ % actual recovery ◦ % recovery potential ◦ Construction waste → Total inflow → Total outflow
GHG performance	**Carbon intensity**

% circular inflow

In the construction stage, the assessing company should follow the same procedure and gather the relevant **% circular inflow data points**.

The difference with the design stage is that the construction stage requires the actual numbers of different material inflows and not estimations.

Companies can obtain the relevant information from the following sources:

- Supplier documentation: product data sheets, material safety data sheets, environmental product declarations (LCAs, other sustainability reporting documents), certifications and compliance reports (LEED, BREEAM)
- Building information modelling tools
- Bill of quantities (BOQ), including costs
- Material takeoff (MTO)
- Bill of materials (BOM), in cases of offsite and modular construction of components and materials for assembly
- Material passports

After gathering the data, the assessing company can use Equation 2 to calculate the % circular inflow indicator.

% circular outflow

As mentioned before, the % circular outflow indicator uses the combination of % recovery potential and % actual recovery. Relevant datapoints for this indicator are:

- % recovery potential of each construction waste outflow
- % recovery potential of the building or project (taken from the design stage)
- % actual recovery per material
- Construction waste masses (kg)
- Building or project material mass (kg)

% recovery potential

In this stage of the building's life-cycle, construction stage companies will refer to the % recovery potential for the whole building or project calculated at the design stage. The logic behind this synergy is that the construction of a building should follow the instructions and the plan the company carefully crafted in the design stage to make the building more circular and sustainable. Therefore, the project would have the same potential for recovery. Additionally, as the design of this methodology aims to increase value chain collaboration between the different parties working on the same building or project, the synergy will enable the facilitation of communication channels and mechanisms to ensure the sharing of data and progress between the two parties.

Additionally, at this stage of the building's life-cycle, the company should calculate the % recovery potential for the construction waste produced during the construction activities. The EU Joint Research Centre (JRC) defines construction waste as the "waste that is generated from the construction of buildings and typically includes oils, concrete, bricks, glass, wood, plasterboard, asbestos, metals and plastics."[39] The CTI methodology considers it by-product flow that can be circular if it is not landfilled or incinerated.

The company needs to determine the **% recovery potential** of each waste flow itself. For most material flows, the **categorization is**:[40]

- The outflow is fully recoverable: % recovery potential = 100%
- The outflow is not recoverable: % recovery potential = 0%
- The outflow has some recovery potential/ biodegradability: % recovery potential = X%

As new technologies emerge, drawing the line between what is considered recoverable and what is not becomes highly complex and for that reason, this methodology does not offer a universal answer. Aligning with the CTI core methodology, if a technical material can remain functionally equivalent for a second life in a technically feasible and economically viable manner, then it can be considered circular. If a company chooses to either downcycle an inorganic or fossil material, turn it into fuel or burn it in any form or shape, it is considered linear.

For renewable or bio-based content (such as wood), the % recovery potential is the percentage of the material flow that can safely return as a nutrient to the biosphere. Additionally, an important factor for materials in the biological cycle is toxicity. According to the CTI core methodology, the material flow has recovery potential if the level of toxins or hazardous substances in it fall between predetermined thresholds (See CTI v4.0 for more information). If not, then the % recovery potential is 0%.

% actual recovery

The company can calculate the building's or project's % actual recovery using Equation 4. For construction waste outflows, % actual recovery is the percentage of materials recovered (through reuse, repurposing or recycling) after the end of the building's or project's construction activities. To calculate circular outflow of one outflow (A), companies can apply **Equation 10**.

Equation 10: Calculation of the circular outflow of a single outflow

$$\% \text{ recovery potential}_A \times \% \text{ actual recovery}_A \times \text{Mass}_A$$

After calculating the individual indicators, the calculation of % circular outflow (total) is the weight-based ratio of the circular to the total outflow mass of the project (**Equation 11**).

Equation 11: % circular outflow (total)

$$\frac{\text{Circular outflow}_{Build} + \text{Circular outflow}_X + \text{Circular outflow}_Y}{\text{Mass}_{Build} + \text{Mass}_X + \text{Mass}_Y}$$

Where:

Circular outflow$_{Build}$: Circular outflow of the building or project

Mass$_{Build}$: The building's or project's material mass

X, Y: Waste outflows

After calculating the % circular outflow, the assessing company can move to determining the % material circularity indicator using Equation 1. Additionally, as high GHG emissions characterize the construction stage, we advise companies in this stage to also calculate the carbon intensity indicator (see Equation 8).

Example

In this high-level example, a construction company wants to calculate the carbon intensity of a 10-story residential building. Table 9 summarizes the data collected from the construction company. For the sake of simplicity, Table 9 does not consider other materials.

By performing the calculations mentioned in Equation 8, the whole building's carbon intensity is 377 kg CO_2e/m^2.

Table 9: Calculating GHG Performance – example

Material	*Mass (kg)*	*Emissions factor*	*Emissions (kg CO_2e)*
Concrete	12,500,000	0.15	1,875,000
Steel	800,000	1.85	1,480,000
Glass	250,000	0.4	100,000
Insulation	50,000	0.3	15,000
Total emissions			3,770,000 kg CO_2e
Total floor area			10,000 m^2

Case study -People's Pavillion, Eindhoven[41]

The People's Pavilion, showcased during 2017 Dutch Design Week in Eindhoven, exemplifies circular economy principles through its innovative use of 100% borrowed and reusable materials. Designed collaboratively by Bureau SLA, Overtreders W and Arup, the 250 m² temporary structure uses no permanent fixings, allowing for the return or repurposing of all components after the event. Key features included prefabricated concrete piles as columns, steel rods from demolished buildings for cross-bracing, and a glass roof borrowed from a greenhouse supplier. The upper façade had over 9,000 colorful plastic shingles, recycled from PET bottles donated by local residents, highlighting community involvement and the potential for the use of waste materials in construction

Figure 8: People's pavilion in Eindhoven, the Netherlands

Life-cycle stage: Operation

After the building's construction, the next stage in a building's life-cycle is operation and maintenance. Operation is the longest stage and focuses on energy and resource efficiency, waste reduction and extending the building's lifespan. By adopting circular economy practices in this stage, companies can achieve lower operational costs from reduced energy and water bills, extended material lifespan and a lower carbon footprint. Table 10 provides a non-exhaustive list of companies that can use CTI for Buildings in the operation stage.

Companies in the operation stage can choose to fill either the whole building layer or the services layer depending on their project. As companies perform minimal actions during operation, we believe that these two layers provide the most efficient structure to assess circularity at this stage of the building's life-cycle.

Operation stage indicators

Companies can use the indicators in Table 11 to perform the CTI assessment in the operation stage. The assessment will lead to forming the % material circularity for the operation stage. While water and energy circularity are important factors for the building's circularity and the CTI core methodology includes the relevant indicators, the first version of CTI for Buildings does not explore the concepts. Future iterations of this work may include the concept of water and energy circularity in buildings.

As the operation stage is more material-focused and less based on design, the assessment structure will align more with the CTI core methodology for product-based assessments.

Table 10: Non-exhaustive list of companies in operation stage

Company	*Role*
Facility management companies	Responsible for ensuring efficient building maintenance and optimizing space use
Energy management companies	Responsible for introducing renewable energy sources into building operations and monitoring energy consumption through smart systems
Maintenance & technical service providers	Responsible for performing routine, preventive and predictive management to ensure equipment and material lifespan extension

Table 11: Indicators for the operation stage

Category	*Indicators*
Material flow	**% material circularity** → % circular inflow ◦ Renewable inflow ◦ Secondary inflow ◦ Recycled inflow → % circular outflow ◦ % actual recovery ◦ % recovery potential ◦ Operation waste → Total inflow → Total outflow
Circular design	**Lifespan (quant.)**

% circular inflow

In operation, the assessing company should follow the same procedure as with the construction stage and gather the relevant **% circular inflow data points.** As with the construction stage, this stage requires the actual numbers of different material inflows and not estimations.

The following sources can provide the relevant information:

- Supplier documentation: product data sheets, material safety data sheets, environmental product declarations (LCAs, other sustainability reporting documents), certifications and compliance reports (LEED, BREEAM etc.)
- Building information modelling tools
- Bill of quantities (BOQ), including costs
- Material takeoff (MTO)
- Bill of materials (BOM), in cases of offsite and modular construction of components and materials for assembly
- Material passports

After gathering the data, the assessing company can use the formula described in **Equation 2** to calculate the % circular inflow.

% circular outflow

To capture the % circular outflow in the operation stage, the calculation uses a combination of % recovery potential and the % actual recovery of the building or project and the by-product material flows. Similar to the procedure of the construction stage, the relevant data points include:

- % recovery potential of each operational waste outflow
- % recovery potential of the building or project (taken from the design stage)
- % actual recovery per material outflow
- Operational waste masses (kg)
- Building or project material mass (kg)

% recovery potential

At this stage of the building's lifetime, the % recovery potential indicator focuses more on the company's project and activities and their operational waste. Companies in the operation stage can refer to the % recovery potential from the design stage (same as construction) to facilitate communication and synergies between different value chain stakeholders.

Additionally, as with the construction stage, the company needs to calculate the material flows of the operational waste generated from the maintenance and daily activities. Operational waste is "waste generated by daily activities."[42] In this guidance it includes the occupancy waste streams and waste generated by maintenance activities, depending on the assessing company's scope and objectives. To assess the % recovery potential of operational waste outflows, assessing companies can use the CTI categorization, reflecting on if the material outflows are recoverable, somewhat recoverable or linear.

Lastly, an important indicator to consider at this stage is the building's or the project's lifespan (quant.). Essentially, this indicator will show if there is a change in lifespan through the maintenance activities, which will increase the building's or project's durability and will be considered at a later stage for the final circularity score of the project.

% actual recovery

The calculation of the building's or project's % actual recovery in the operation stage also uses Equation 4. For the operational waste outflows, % actual recovery is the percentage of materials recovered (through reuse, repurposing or recycling) after the end of maintenance activities or their disposal (for occupancy-generated waste). After gathering the relevant data points, the assessing company can use Equation 10 and Equation 11 respectively to calculate the circular outflow mass for each material outflow and the % circular outflow (total) for the project.

The next step is to capture the % material circularity indicator, using Equation 1.

Example

In this high-level example, a facility management company is looking to calculate the % circular outflow for the whole building layer of their residential project, following HVAC system maintenance. Table 12 summarizes the data points required to calculate the % circular outflow.

After gathering the data, the first step is to calculate the circular outflow for each material outflow:

- Circular outflow$_{Build}$= 75% x 55% x 15,000,000 = 6,187,500 kg
- Circular outflow$_{Insulation}$= 90% x 70% x 300 = 189 kg
- Circular outflow$_{Metal}$= 60% x 90% x 500 = 270 kg

The next step, is to calculate the % circular outflow for the whole project in the construction phase, using **Equation 11**:

$$\frac{6{,}187{,}500 + 189 + 270}{15{,}000{,}000 + 300 + 500} = 41\%$$

As with the other examples, even before calculating the final result, the areas that the company can focus on are clear. For example, it could further improve the % recovery potential of the insulation material by partnering with suppliers that ensure high recoverability rates for insulation materials.

Table 12: Calculation of % circular outflow - example

Material outflow	*Mass (kg)*	*% recovery potential*	*% actual recovery*
Building	15,000,000	75%	55%
Insulation material (waste outflow 1)	300	90%	70%
Metal components (waste outflow 2)	500	60%	90%

Life-cycle stage: Retrofit

The building's retrofitting stage includes all the renovation cycles and activities that (different) companies perform in a building. Companies execute renovations at different times in a building's life-cycle to increase efficiency, extend the lifespan, comply with new regulations, increase the building's value, address health and safety concerns and preserve the building's historical or cultural value. By adopting circular economy strategies during the retrofitting cycles, the building can become more durable and minimize its environmental impact. Table 13 provides a non-exhaustive list of relevant companies for this stage.

In this stage of the building's life-cycle, companies have the flexibility to perform the assessment at either the whole building level or on a single layer, based on the objectives of the assessment. Note that the company can perform the assessment multiple times at this stage, as most buildings undergo more than one renovation cycle during their lifespan – often exceeding the number initially planned in the design phase. The companies should perform the assessment after each renovation cycle and we highly encourage communication between the companies involved in each cycle to ensure the highest quality of data and insights produced. As with the construction stage, material suppliers and manufacturers can also use the CTI core methodology at this stage, as it is more product-oriented than CTI for Buildings.

Table 13: Non-exhaustive list of companies in retrofitting stage

Company	*Role*
Architecture and design firms	Responsible for sustainable retrofitting, adaptive reuse of materials and space optimization
Engineering firms	Responsible for handling structural upgrades and sustainable construction practices
Interior designers	Responsible for designing layouts, materials, lighting and furnishings
Sustainability consulting firms	Responsible for sustainability certification, eco-friendly materials and energy efficiency
Material suppliers & manufacturers	Responsible for providing building materials such as steel, concrete, insulation, wood and glass.

Retrofitting stage indicators

Companies involved in the retrofitting stage can use the following indicators to assess their circular performance with the CTI for Buildings methodology. As with the rest of the building's life-cycle stages, the assessment will culminate with the % material circularity indicator. Table 14 summarizes the retrofitting stage indicators.

Table 14: Indicators for the retrofitting stage

Category	*Indicators*

Material flow	**% material circularity**
	→ % circular inflow
	  ◦ Renewable inflow
	  ◦ Secondary inflow
	  ◦ Recycled inflow
	→ % circular outflow
	  ◦ % actual recovery
	  ◦ % recovery potential
	  ◦ Construction waste
	→ Total inflow
	→ Total outflow

Circular design	**% recovery potential (*)** → Adaptable building → Adaptable floor area → Component disassembly (qual.) → Component disassembly (quant.) → Material passport → Reuse plan → Lifespan → Material flow analysis → Modularity (qual.) → Modularity (quant.) → Refuse new construction → Refuse unnecessary components
GHG Performance	**Carbon intensity**

% circular inflow

The calculation of the % circular inflow for the retrofitting stage uses Equation 2 and the relevant % circular inflow data points. As retrofitting includes the addition of new components, the required data points need to reflect the actual numbers and not estimations.

Relevant data sources include:

- Supplier documentation: product data sheets, material safety data sheets, environmental product declarations (LCAs, other sustainability reporting documents), certifications and compliance reports (LEED, BREEAM, etc.)
- Building information modelling tools
- Bill of quantities (BOQ), including costs
- Material takeoff (MTO)
- Bill of materials (BOM), in cases of offsite and modular construction of components and materials for assembly
- Material passports

Example

In this high-level example, an engineering firm is responsible for renovating the outer layer of the front façade of the residential building mentioned in the other examples above. After extensive data collection efforts, it has created a summary of the material inflows. Table 15 provides the information relative to calculating the % circular inflow for this example.

Following Equation 2, the % circular inflow of the project at this stage is 39%. What the company could do to increase the circular inflow is to substitute some of the materials with sustainably managed renewable alternatives. For example, it could use wood fiber composites for the fiber cement panels or lime-based stucco.

Table 15: Calculating % circular inflow - example

Material outflow	*Mass (kg)*	*% recycled content*	*% reused content*	*% renewable content*
Brick veneer	56,000	0%	40%	0%
Metal panels	5,250	50%	20%	0%
Fiber cement panels	7,875	65%	0%	0%
Natural or engineered stone	15,750	0%	20%	0%
Stucco	5,250	0%	0%	0%
Total	90,125	9%	30%	0%

% circular outflow

The % circular outflow indicator in this stage uses a combination of % recovery potential and % actual recovery for both the whole building or project and the construction waste outflows. Relevant datapoints for this indicator are:

- % recovery potential of each construction waste outflow
- % recovery potential of the building or project
- % actual recovery per material
- Construction waste masses (kg)
- Building or project material mass (kg)

% recovery potential

Recovery potential in the retrofitting stage is a combination of the methodologies followed in the design and construction stages. As the building receives new components, the company should assess its recoverability again based on the current adoption of circular design practices. However, while companies can perform the assessment on the whole building layer, it is very rare for renovations to cover the whole building all at once. Therefore, we do not include indicators that reflect such a design principle in the list of indicators for this stage. The excluded design principles are utilization and flexibility. Assessing companies can use a **revised version Equation 3**, as follows:

$$\frac{AP_{Ad} + AP_{Dem} + AP_{Long} + AP_{MU} + AP_{Ref} + AP_{Mod}}{6}$$

As with the design stage, if a company does not deem a strategy relevant, it can exclude it as long as it provides the relevant documentation to justify the exclusion.

Additionally, as with the construction stage, the company needs to calculate the % recovery potential indicator for the by-product material flows of the construction waste generated from relevant activities. The company can do so using the CTI categorization, reflecting on if the material outflows are recoverable, somewhat recoverable or linear.

% actual recovery

Assessing companies in the retrofitting stage can use Equation 4. For construction waste outflows, % actual recovery is the percentage of materials recovered (through reuse, repurposing or recycling) after the end of the building's or project's retrofitting construction activities. To calculate the circular outflow mass of an individual outflow and the % circular outflow (total), companies may use the formula outlined in Equation 10 and Equation 11 respectively.

After calculating the % circular outflow, the assessing company can move to determining the % material circularity indicator, using Equation 1. Additionally, as the retrofitting stage includes construction activities characterized by high GHG emissions, we encourage companies in this stage to also calculate the carbon intensity using Equation 8.

Case study – Haus Neumarkt, Cologne[43]

Arup's refurbishment of Cologne's Haus Neumarkt exemplifies circular construction principles by preserving the building's original 1950s charm while integrating sustainable innovations. The project reconstructed the natural stone façade using recyclable materials and simple plug-in connections, facilitating future disassembly and reducing resource consumption. By retaining the existing reinforced concrete structure, the renovation avoided the need for approximately 1,600 m² of new concrete, thereby preventing around 2,500 metric tons of CO_2 emissions. This approach highlights the environmental benefits of material reuse and design for deconstruction in sustainable building practices.

Figure 9: The before and after of Haus Neumarkt in Cologne, Germany

Life-cycle stage: Deconstruction

The deconstruction stage is the last phase of a building's lifetime and, as mentioned above, it signals the building's end of life, when it can no longer be used or altered. The focus of this stage is more material-centric, as the companies involved should aim for circular deconstruction practices, material recoverability and digital tracking for material traceability purposes. Circular design practices planned in the design and retrofitting stages, such as demountability and material reuse, come into effect to ensure waste and GHG emissions minimization, efficient material recovery and the reintegration into a new project, enabling closed loops. Table 16 provides a non-exhaustive list of companies included in this stage of a building's life-cycle. As with the design stage, if a company does not deem a strategy relevant, it can exclude it as long as it provides the relevant documentation to justify the exclusion.

Additionally, as with the construction stage, the company needs to calculate the % recovery potential indicator for the by-product material flows of the construction waste generated from relevant activities. The company can do so using the CTI categorization, reflecting on if the material outflows are recoverable, somewhat recoverable or linear.

In this stage of the building's life-cycle, companies can only perform the assessment on the whole building layer, as we believe that they can more efficiently capture circularity in the whole building layer at the end of life. In cases where there is only partial deconstruction to preserve parts of the building, the assessing company can still use the whole building layer, employing the remaining parts of the building as recovered outflow.

Indicators for the deconstruction stage

In this final stage of the building's life-cycle, companies can use the indicators in Table 17 to perform the CTI assessment. As the assessment will revolve around sustainable material recovery, from the deconstruction activities, the focus will be more material-centric and lead into forming the % material circularity for the deconstruction stage.

As mentioned before, at this stage the methodology also focuses on the actual durability of the building, measured by the Actual lifespan indicator. The difference between the two numbers will result in the LF, which the company will multiply with the final circularity score of the building, aiming to reward those that extended the original lifespan decided in the design stage.

Table 16: Non-exhaustive list of companies in the deconstruction phase

Company	*Role*
Specialized deconstruction and circular demolition firms	Responsible for sustainable deconstruction and material reuse
Recycling and waste management companies	Responsible for handling material recovery and recycling, especially for demolition waste circularity

Table 17: Indicators for the deconstruction stage

Category	*Indicators*

Material flow	→ **% material circularity**
	→ % circular inflow
	→ % circular outflow
	  ◦ % actual recovery
	  ◦ % recovery potential
	  ◦ Demolition waste
	→ Total inflow
	→ Total outflow

Circular design	**Actual lifespan**
GHG Performance	**Carbon intensity**

% circular inflow

In the last stage of the building's life-cycle, the focus shifts from introducing materials into the building to material recovery from the building, as no more retrofitting activities would take place after this stage (end of life). Hence, companies in the deconstruction stage will refer to the % circular inflow from the retrofitting stage as well and use it to calculate % material circularity indicator.

% circular outflow

In the deconstruction phase, the % circular outflow indicator uses the combination of % recovery potential and % actual recovery for both the whole building or project and the demolition waste outflows.

% recovery potential

As mentioned above, the deconstruction stage considers two different cases: complete deconstruction and selective deconstruction. In both cases, the % recovery potential indicator is a combination of the building's % recovery potential and the demolition waste outflows % recovery potential. The first one comes from the retrofitting stage to facilitate communication and synergies between different value chain stakeholders. Demolition waste is "Debris that is generated through demolition activities, including bulky materials, such as concrete, wood, gypsum, metals, bricks, glass, plastics and salvaged building components."[44] As with construction and operational waste, the CTI for Buildings methodology considers it a by-product outflow if it does not end up in a landfill or incinerated. Assessing companies in this stage can use the **CTI categorization** to determine the recoverability of each by-product outflow based on if it is recoverable, somewhat recoverable or linear.

% actual recovery

At this stage, instead of looking at recovery standards to calculate the % actual recovery, companies need to use real numbers from the materials actually recovered after the deconstruction activities.

As mentioned above, this stage considers two different cases: holistic and partial deconstruction. Relevant datapoints for this indicator in both cases include:

- → % recovery potential of each by-product outflow (demolition waste streams)
- → % recovery potential of the building or project (taken from the retrofitting stage)
- → % actual recovery per material (building and demolition waste streams)
- → Building or project material mass (kg)

The difference between the two cases is in adding the mass of the retained building structure to the material mass recovered after the deconstruction activities, in the case of partial deconstruction and possible expansion of the building. After collecting the data, companies can use **Equation 4**. For the demolition waste outflows, % actual recovery is the percentage of materials recovered (through reuse, repurposing or recycling) after the end of the building's deconstruction activities. To calculate the circular outflow mass of an individual outflow and the % circular outflow (total), companies may use the formula outlined in **Equation 10** and **Equation 11**.

After calculating the % circular outflow, the assessing company can move to determining the % material circularity indicator, using **Equation 1**. Additionally, as the deconstruction stage includes high GHG emissions activities, we encourage companies in this stage to also calculate the carbon intensity, using **Equation 8**.

Example

A contractor is responsible for the partial deconstruction of the three top floors of a 10-story residential building. For simplicity, Table 18 shows only those materials we consider as included in the building.

The calculation of % actual recovery uses the combination of the preserved mass percentage and the % actual recovery of the deconstructed material. For example, in concrete, the company preserved 70% of the total mass and recovered 40% of the deconstructed mass. This means the company recovered 4,100,000 kg of concrete in total, thus 82% of the total mass. The same methodology applies to the rest of the materials. Table 19 shows the same exercise for demolition waste streams of the deconstruction activities.

By leveraging Equation 10 and Equation 11, the % circular outflow of the project would be 49%.

Table 18: Calculating partial deconstruction - example A

Material outflow	*Mass (kg)*	*Deconstructed (kg)*	*Preserved (kg)*	*% recovery potential*	*% actual recovery (preserved + recovered)*
Concrete	5,000,000	1,500,000	3,500,000	50%	82% (70% preserved and 40% recovered from the deconstructed mass)
Steel	500,000	150,000	350,000	95%	94% (70% preserved and 80% recovered from the deconstructed mass)
Brick	1,000,000	300,000	700,000	70%	91% (70% preserved and 70% recovered from the deconstructed mass)
Wood	300,000	90,000	210,000	80%	88% (70% preserved and 60% recovered from the deconstructed mass)
Glass	100,000	30,000	70,000	60%	79% (70% preserved and 30% recovered from the deconstructed mass)

Table 19: Calculating partial deconstruction - example B

Material outflow	*Mass (kg)*	*% recovery potential*	*% actual recovery*
Steel (waste outflow 1)	30,000	95%	68%
Bricks (waste outflow 2)	90,000	90%	70%
Flat glass (waste outflow 3)	9,000	100%	30%

Case study – De Drait sports hall, Drachten[45]

The circular deconstruction of the De Drait sports hall in Drachten, Netherlands, exemplifies sustainable building practices by prioritizing the reuse of materials from the original structure. Wind Design + Build, in collaboration with the municipality of Smallingerland, retained 80% of the existing foundation and repurposed various components such as steel structural elements, wooden ceilings, and interior fixtures like benches and coat hooks. Materials unsuitable for reuse in the new facility were carefully dismantled and directed to a circular intermediate station for potential application in other projects. This meticulous approach not only diverted 90–95% of building materials from landfills but also minimized environmental impact through reduced demolition work and transportation needs, setting a benchmark for circular construction in the region.

Figure 10: De Drait sports hall in Drachten, the Netherlands

Applying the Longevity Factor and calculating the final circularity score

After the end of the building's life-cycle, the company needs to calculate the final circularity of the building. The final score will be an aggregation of the % material circularity indicators from all stages of the building's life-cycle, multiplied by the LF to promote durability and longevity in the built environment.

Example
In the example of the residential building, and considering that the building was fully deconstructed after 70 years, Table 20 summarizes the % material circularity indicators for all stages, along with the difference in the planned versus actual lifespan.

The final circularity score would be the aggregation of the % material circularity scores of the five building lifecycle stages multiplied by the LF. Equation 7 provides the final circularity score of the building.

$$\frac{60\% + 50\% + 70\% + 65\% + 70\%}{5} \times \frac{70}{60} = 69\%$$

Table 20: Calculating final circularity score

	Design	*Construction*	*Operation*	*Retrofitting*	*Deconstruction*	*△ Lifespan*
% material circularity	60%	50%	70%	65%	70%	10
Total circularity score	69%					

Next steps

As with the CTI core methodology, CTI for Buildings is first and foremost a process cycle that begins with setting the objectives and the scope of the methodology and ends with the prioritization of actions and target setting. After calculating the % material circularity for the life-cycle stage the project is in, the company needs to analyze the results, prioritize actions based on identifying circular risks and opportunities and set targets to monitor progress. For more information on how to proceed with the last three steps of the CTI process cycle, see the latest CTI report (CTI v4.0).

Note that as the company is meant to repeat the process after each life-cycle stage, it can use the results of the calculations as a communication tool between built environment value chain stakeholders to enable discussions on identifying circularity gaps and improvement points in the same building, from one stage to another. Additionally, the assessing company can use the calculation results from different projects in the same building life-cycle stage to identify lessons learned and improvement opportunities and improve internal decision-making. This exercise can reveal new circularity objectives for the company that it can use during the scoping process of the next assessment.

CTI for Buildings v1.0 introduces a foundational set of core indicators to evaluate circular material use in alignment with WBCSD's Circular Transition Indicators (CTI) methodology. These indicators were developed through extensive consultation with leading stakeholders and experts in the circular built environment.

A truly comprehensive assessment of circular performance will also require consideration of additional dimensions—such as water circularity, the carbon implications of circular resource flows, key pressures on biodiversity, and social equity impacts. Future iterations of this guide are expected to expand the indicator set to more fully capture circularity across the built environment value chain. Meanwhile, users of this guidance can draw on CTI v4.0, CTI Social Impact, and the Global Circularity Protocol for Business, which collectively begin to address these dimensions through a cross-sectoral lens.

In parallel, users of the CTI framework can leverage **WBCSD's** CTI Enabling Solutions guidance to support credible, data-driven claims about products, services and activities that enhance circularity for clients and stakeholders.

Conclusion

03.

04. Conclusion

As the world continues to face a resource crisis where demand is outstripping supply, the built environment is at a critical juncture. As a sector responsible for nearly 40% of global carbon emissions and over a third of the world's resource consumption, its current linear model – characterized by resource extraction, energy-intensive production and wasteful end-of-life practices – is no longer sustainable.

The transition towards circular business models offers a transformative solution and represents an unprecedented opportunity for systemic transformation and the creation of a sustainable global economy that delivers positive outcomes for both people and the planet. Circular business models – such as designing for adaptability and longevity – ensuring material recovery and extending the building's lifespan – present a significant opportunity to reduce waste, lower embodied carbon and unlock long-term economic benefits. Studies suggest that circular construction strategies can lead to emissions and waste reductions, while the reuse of secondary materials alone has the potential to substantially reduce demand for virgin resources and stimulate new economic opportunities across the sector.

Strong regulatory frameworks, investor expectations and shifting consumer preferences are further accelerating the adoption of circular practices. Policies such as the Corporate Sustainability Reporting Directive (CSRD), extended producer responsibility (EPR), mandatory material passports, and embodied carbon regulations are shaping a more sustainable and accountable sector. At the same time, innovations in material science, modular construction and digital platforms have the potential to enable and scale circularity more than ever before.

Achieving a truly circular built environment requires collaboration between the entire value chain. Stakeholders from the entire built environment value chain, such as architects, developers, policymakers, material suppliers and waste managers, must work together to close material loops and integrate circularity at every stage of a building's life-cycle. To drive this transition, there is a need for the sector to establish clear benchmarks, create financial incentives and implement strategies that prioritize resource efficiency and long-term resilience.

Through the methodology in this guidance and in CTI v4.0, WBCSD enables companies in the sector to measure and improve the circular performance of their buildings and projects. Its tailored metrics, definitions, principles and strategies foster value chain collaboration and value creation and ensure that materials, components and buildings remain in use at their highest value for as long as possible.

We encourage all stakeholders in the built environment to adopt CTI as the preferred framework for measuring and managing their circular performance. By embracing a shared language and a unified approach to circularity, the sector can collectively transition to a more resource-efficient, low-carbon and regenerative built environment – one where materials retain their highest value and where companies minimize waste and embed sustainability at every stage of the building life-cycle.

WBCSD stands ready to help companies successfully navigate their transition to circularity and drive systemic actions towards a more resilient and sustainable built environment.

Annex: List of CTI for Buildings indicators

The complete list of indicators used in the CTI for Buildings Methodology

Category	*Indicators*	*Description*	*Units*	*Building life-cycle stages*
Circular design	**% recovery potential (*)**	What percentage of a building's/project's total mass is designed for recovery at the end of each life-cycle stage?	%	All
	→ Adaptable building	Is the building adaptable to a different function in the future?	Yes or No	Design, retrofitting
	→ Expansion	Does the site allow for vertical or horizontal expansion of the building?	Yes or No	Design
	→ Adaptable floor area	What percentage of the total floor area can be adapted to a different function in the future?	% (m^2)	Design, retrofitting
	→ Component disassembly	Does the component installation consider design for disassembly practices for non-destructive removal?	Yes or No	Design, retrofitting
	→ Component disassembly	What percentage of components can be disassembled without significant damage? (Having: the ability to reuse the component on the same level of functionality)	% (kg)	Design, retrofitting
	→ Material passport	What percentage of materials have an available material passport?	% (kg)	Design, retrofitting
	→ Reuse plan	What percentage of components/materials have a plan for reuse or recycling?	% (kg)	Design, retrofitting
	→ Multi-use space	Is it possible to use the space or rooms in the building for other purposes (e.g., from office space to auditorium)?	Yes or No	Design
	→ Multi-use space	What percentage of the total floor area can be used for a different purpose?	% (m^2)	Design
	→ Design for robustness	Has your design considered design for future climate resilience and/or robustness?	Yes or No	Design
	→ Lifespan	Has your design considered all the relevant aspects of a building's durability to maximize the building's lifespan?	Yes or No	Design, retrofitting
	→ Lifespan (actual lifespan for deconstruction stage)	What is the expected/actual lifespan of the building?	years	Design, operation, retrofitting, demolition
	→ Retrofit	What is the expected renovation cycle? Has it changed after the first renovation?	years	Design
	→ Material flow analysis	Have you undertaken a material flow analysis, including a whole life-cycle carbon analysis?	Yes or No	Design, retrofitting
	→ Modularity	Are modular construction methods used?	Yes or No	Design, retrofitting
	→ Modularity	What % of components were constructed using modular methods?	% (kg)	Design, retrofitting
	→ Refuse new construction	Have you exhausted all options to refuse new construction before proceeding?	Yes or No	Design, retrofitting
	→ Refuse unnecessary components	Has the design considered refusing unnecessary components and finishes?	Yes or No	Design, retrofitting
	→ Flexibility	What percentage of the total floor area is flexible enough to accommodate a change in layout with the same function?	% m^2	Design

Category	*Indicators*	*Description*	*Units*	*Building life-cycle stages*
Material flow	**% material circularity**	What is the weight-based ratio of % circular inflow & % circular outflow?	% (kg)	All
	→ % circular inflow	What is the percentage of circular content of the materials used?	kg	All
	◦ Renewable inflow	What is the percentage of the renewable materials used?	% (kg)	All
	◦ Secondary inflow	What is the percentage of the reused/recovered materials used?	% (kg)	All
	◦ Recycled inflow	What is the percentage of the non-virgin materials used?	% (kg)	All
	→ Total inflow	What is the total mass of materials used?	kg	All
	→ % circular outflow	What is the percentage of the circular content of materials recovered at the end of each building life-cycle stage?	% (kg)	All
	◦ % recovery potential (*)	See Circular design		
	◦ % actual recovery	What percentage of a building's/project's or waste stream's total mass was recovered at the end of each building life-cycle stage?	% (kg)	All
	◦ Construction waste	What percentage of construction waste generated is reused, recycled or landfilled?	% (kg)	Construction, retrofitting
	◦ Demolition waste	What percentage of demolition waste generated is reused, recycled or landfilled?	% (kg)	Deconstruction
	◦ Operational waste	What percentage of operational waste generated is reused, recycled or landfilled?	% (kg)	Operation
	→ Total outflow	What is the total outflow mass (including building material mass and waste flows such as construction waste)?	kg	All
GHG performance	Carbon intensity	What are the total CO_2 emissions of the building or building activity for the year of the assessment?	kg CO_2/m^2	Construction, retrofitting, deconstruction

Glossary

Adaptability (in the built environment)
The ability to be modified or repurposed over time with minimal structural changes to accommodate different uses, functions, or user needs across the whole lifespan (for example changes in occupancy, accessibility requirements, or technological upgrades).[46]

Building Layers
In the context of architecture and building design, the concept of Building Layers refers to the idea that different components of a building have varying lifespans and rates of change. This framework was initially introduced by architect Frank Duffy and later expanded upon by Stewart Brand in his book How Buildings Learn: What Happens After They're Built (1994). Brand identified six primary layers, each with distinct characteristics and expected durations:[47]

- **Site:** The geographical setting and legally defined lot, which is considered permanent and unchanging
- **Structure:** The foundation and load-bearing elements of the building
- **Skin:** The exterior surfaces, such as facades and roofing
- **Services:** The essential systems that make the building functional, including electrical wiring, plumbing, and Heating, Ventilation and Air Conditioning systems
- **Space plan:** The interior layout, encompassing walls, ceilings and doors
- **Stuff:** The furnishings and personal items within the building.

Carbon Intensity
The annual amount of carbon dioxide equivalent (CO_2e) emitted per square foot of real estate.[48]

Circular Inflow
Inflow that is:

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

OR

- Non-virgin (see definition for Secondary)

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

Construction waste
The waste that is generated from the construction of buildings and typically includes oils, concrete, bricks, glass, wood, plasterboard, asbestos, metals and plastics.[49]

Demolition waste[50]
Debris that is generated through demolition activities, including bulky materials, such as concrete, wood, gypsum, metals, bricks, glass, plastics and salvaged building components.[51]

Downcycling
Recycling "something in such a way that the resulting product is of lower (economic) value than the original item".[52]

Durability
The ability of a building or component to function as required, under specified conditions of use, maintenance and repair, until a limiting event prevents its functioning.

Expansion

In the context of the built environment, building expansion refers to the process of increasing a structure's size or capacity to accommodate additional space or functions.[53] The expansion can be achieved through various methods:

- **Horizontal Expansion:** Extending the building's footprint at ground level by adding new sections to the sides or rear of the existing structure
- **Vertical Expansion:** Adding new floors or stories atop the existing structure, utilizing the current foundation and framework to support upward growth.

Functional Equivalence
"The state or property of being equivalent" (or equal) in function.[54] In the context of CTI, this defines an outflow (a component, waste stream, etc.) designed so that it is technically feasible and economically viable to bring it back to inflow (as a component, a material etc.) preserving a similar function to its previous cycle. For example, a reclaimed timber beam from a deconstructed warehouse can be used to provide comparable structural support in a new residential building, after the safety assessments.

Lifespan
The lifetime of a building is defined as the duration over which it remains functional, meeting the needs that was designed for from when it is first built to when it is demolished.[55]

Lifecycle Assessment (LCA)
ISO 14040 defines LCA as "the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life-cycle".[56]

Linear Inflow
Virgin, non-renewable resources

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

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

OR

→ Neither demonstrably recovered nor flowing back into the economy

Longevity
The term refers to "long duration of individual life".[57] In the context of buildings, the term refers to the long duration over which a building remains functional, safe, and relevant to its intended use. Achieving longevity involves designing and constructing buildings that can endure over time with minimal need for major repairs or renovations.

Material Flow
Material flows can include nutrients, compounds, materials, parts, components or even products. This guidance refers to all of these as material flows.

Modular
In the context of building design and construction, modular refers to a design approach that divides a building into smaller, prefabricated sections called modules that are constructed off-site in a controlled factory environment and then transported to the building site for assembly.[58]

Multi-use space
In building design, multi-use space is an area designed to accommodate a variety of activities and purposes within a single environment.[59] For example, a community centre may feature a large open area equipped with movable walls and modular furniture, enabling it to host fitness classes in the morning, educational workshops in the afternoon, and social events in the evening.

Operational waste
The waste generated by daily activities,[60] including occupancy waste streams and/or waste generated by maintenance activities.

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 (see definition above) through reuse, repair, refurbishing, repurposing, remanufacturing, recycling or biodegrading. This excludes energy recovery from waste and any biological cycle waste that does not satisfy the following criteria:

1. Other end-of-life options, besides landfill, must have been exhausted (in terms of technical capability and economic viability).
2. The material must be from a biological source.
3. The biological material must be demonstrably from a source of sustained production (i.e., regeneratively produced).
4. The biological material must be uncontaminated by technical materials – except where these are demonstrably inert and nontoxic.
5. Energy recovery must be optimized and the energy usefully employed to displace non-renewable alternatives.
6. The by-products of the energy recovery must themselves be biologically beneficial and must not be detrimental to the ecosystems to which they are introduced. (See CTI v4.0 page 50 for more guidance).

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 or butterfly diagram[61]):

- **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.

Retrofit

Retrofits are defined as any intervention within the building to adjust, reuse, or upgrade it to suit new conditions or requirements.[62]

Renewable Inflow

Aligning with ISO 21930 and LEED, renewable inflow is defined as sustainably managed resources, most often demonstrated by internationally recognized certification schemes like the Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification (PEFC), Roundtable on Sustainable Palm Oil (RSPO), etc. 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. In CTI for Buildings, renewable inflow examples could be FSC-certified timber, cellulose insulation created from FSC-certified recycled paper and FSC-certified wood shingles.

Robustness

In buildings' design, robustness refers to the ability of a building to perform effectively under various conditions, remaining functional and safe and retaining its aesthetics.[63]

Secondary Inflow

Inflow previously used (non-virgin), e.g. recycled materials, recovered components etc.

- **Reused Inflow:** According to LEED certification, reused inflow pertains to materials or components that are directly repurposed in new products (or buildings) without significant alteration
- **Recycled inflow:** According to ISO 14021, recycled inflow is defined as the materials diverted from waste streams during manufacturing, excluding reutilization within the same process.

Virgin Inflow

Inflow not previously used or consumed (primary).

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Disclaimer

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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. The Circular Transition Indicators v1.0, v2.0, v3.0, v4.0 by the World Business Council for Sustainable Development are licensed under CC BY-ND 4.0 (Creative Commons Attribution-NoDerivatives 4.0 International).

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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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