The Circularity Gap Report 2025

CGR 2025

A circular economy to live within the safe limits of the planet

CIRCLE ECONOMY

Behind the cover

This year's cover captures a stark contrast: desert encroaching on lush forest. It's a powerful visual metaphor for our current trajectory—where resource overuse and environmental degradation threaten to erase what remains green and vital. The circular economy offers a path to push back the desert, both literally and figuratively, by restoring balance between people, planet, and prosperity.

Circle Economy is driving the transition to a new economy. In this economy we help businesses, cities and nations leverage business opportunities, reduce costs, create jobs and inspire behavioural change. As a global impact organisation, our international team equips business leaders and policymakers with the insights, strategies, and tools to turn circular ambition into action.

Circle Economy has been at the forefront of the circular economy transition since 2012. Our annual *Circularity Gap Report* sets the standard for measuring progress and we manage the world's largest circularity database, encompassing data from over 90 nations, 350 cities, and 1,000 businesses.

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In support of the *Circularity Gap Report*

Dr Jack Barrie

Senior Research Fellow, Royal Institute of International Affairs

'The *Circularity Gap Report* has become a key measure of progress in the global transition to a circular economy. The 2025 report reveals how far the world is from achieving a truly regenerative circular system—and, as a result, how vulnerable economies are to increasing resource volatility and competition. It also provides a global benchmark—a critical reference point from which to accelerate progress—alongside a compelling case showing why urgent global action is needed today.'

Atte Jääskeläinen

President, The Finnish Innovation Fund Sitra

'Amid rising geopolitical tensions, resource competition, and economic volatility, the circular economy is more important than ever. It plays a key role in driving new investments, shaping free-trade agreements, and strengthening development cooperation—such as the support provided by the new Sitra-led EU Circular Economy Resource Centre. The world's resource flows are changing, and this report manages to both stress the urgency of transitioning while capturing the opportunities a circular economy offers.'

Hege Sæbjørnsen

Global Circular Strategy Leader, Ingka Group, IKEA

'Businesses play a crucial role in scaling circular solutions, and brands, in particular, have the power to mobilise consumers across the globe and drive behavioural change. By rethinking product design, investing in new business models, and developing new capabilities, the private sector can accelerate the transition towards a circular economy. The *Circularity Gap Report* is a valuable tool that provides insights, informs better actions, and suggests impactful indicators for progress.'

In support of the *Circularity Gap Report*

Dr Mohab Ali Al-Hinai

Vice President Sustainability & Circular Economy, be'ah

'At be'ah, we believe that circularity is the foundation for a sustainable future. The *Circularity Gap Report 2025* highlights the urgent need for systemic change, reinforcing the role of collaboration, innovation, and responsible resource use in shaping a resilient global economy. We are proud to support this initiative and remain committed to driving impactful change for Oman and beyond.'

Helena McLeod

Deputy Director-General and Head of Green Growth Planning & Implementation Division, Global Green Growth Institute

'Despite widespread discussions on the circular economy, the world is becoming less circular. I commend the *Circularity Gap Reports* for bringing this urgent issue to light. Its call is clear: nations must urgently shift to a circular economy to build resilience and sustainability. We look forward to more region- and country-specific assessments and the formal adoption of circularity metrics in national and regional policy frameworks.'

HRH Princess Sumaya bint El Hassan

President, The Royal Scientific Society of Jordan

'To unleash the full potential of circularity and help raise the global Circularity Metric beyond its current 6.9%, we hope that the *Circularity Gap Report 2025* will serve as a catalyst for informed, data-driven action. Such action is essential for accelerating the global transition towards a circular economy. This will help address the triple planetary crisis of climate change, biodiversity loss, and pollution, while advancing human well-being within the limits of our planet. In Jordan, where resource scarcity and environmental pressures are keenly felt, the case for circularity is both urgent and compelling. At the Royal Scientific Society, we remain steadfast in our commitment to advancing circular economy principles through innovation, collaboration, and regional leadership. We believe that Jordan can serve as a model for practical, scalable solutions that respect both people and planet.'

In support of the *Circularity Gap Report*

Janez Potočnik
Co-Chair, International Resource Panel

'The *Circularity Gap Report 2025* highlights that, more than ever, urgent action to boost circularity is required from policymakers and industry leaders. The transition needs to be guided by science-based targets for material consumption, particularly in high-income countries, which are overshooting the safe and just boundaries of our planet.'

Elisabeth Türk
Director of Economic Cooperation and Trade Division, United Nations Economic Commission for Europe

'The *Circularity Gap Report 2025* highlights the crucial role of governments in driving the circular transition through smart policies and multilateral collaboration. UNECE supports this goal by providing policy tools that leverage trade, innovation, and infrastructure financing, while fostering cooperation through Circular STEP—a network of government experts working to bridge the Circularity Gap in line with the UN's Sustainable Development Goal 12 on sustainable consumption and production.'

Quentin Drewell
Senior Director, Circular Products and Materials, World Business Council for Sustainable Development

'Circular solutions are the only way for businesses to meet both their growth ambitions and global sustainability targets. The *Circularity Gap Report 2025* provides critical insights that help bridge the gap between circular potential and action. Aligning with initiatives like the Global Circularity Protocol, this report plays a crucial role in guiding business leaders toward measurable and transformative actions to ensure businesses can generate long-term value and build up resilience.'

Seema Arora
Deputy Director General, Confederation of Indian Industry

'Globally, there is an urgent need for bold, innovative solutions that drive a systemic shift towards a circular economy. Incorporating circular principles will play a critical role in building competitiveness and addressing socioeconomic development challenges. The Confederation of Indian Industry recognises the importance of transparent, robust data—as provided and championed by the *Circularity Gap Report 2025*—to inform decision-makers and create an enabling policy environment within which industry can act.'

In support of the *Circularity Gap Report*

Heike Vesper

Chief Executive, Transformation & Policies, WWF Germany

'Circularity requires resource-light consumption, circular business models and ambitious policy targets. This year's *Circularity Gap Report* highlights the missing link in circularity: we must reduce our overall material footprint and waste generation. Reuse and lifetime extension are crucial. Policymakers must implement economic conditions for circularity to thrive, and businesses must scale impactful strategies and drive systemic change.'

Johanna Pakarinen

Senior Advisor, Statistics Finland

'The data-driven approach taken by the *Circularity Gap Report 2025* emphasises the critical role of metrics in advancing the circular economy. By measuring and analysing how resources are used, the report provides essential insights for informed decision-making on sustainability, highlighting the importance of tracking material flows in achieving a resilient future.'

Smail Al Hilali

Chief, Division of Circular Economy & Green Industry, United Nations Industrial Development Organization

'The *Circularity Gap Report 2025* is a decisive wake-up call. By revealing our declining circularity and emphasising the urgent need for systemic change, it provides a roadmap for clean industrial transformation that can address climate, nature and economic risks. UNIDO supports these efforts through a broad range of technical cooperation services on the circular economy.'

Dr Zsuzsanna Király

Deputy Secretary General, Central European Initiative

'I fully endorse the *Circularity Gap Report 2025* and its Circularity Metric for the insightful overview of the transition to a circular economy it provides. While this shift presents a substantial challenge for the Central European Initiative region, it also offers significant opportunities to strengthen local economies, empower communities, and foster sustainable development and resilience.'

In support of the *Circularity Gap Report*

Fabian Farkas
Chief Markets Officer, Forest Stewardship Council International

'The *Circularity Gap Report 2025* rightly highlights the urgency of transitioning to a circular economy. The Forest Stewardship Council supports its call for regenerative systems that prioritise renewable, responsibly sourced, and reused materials. This keeps value in the loop and ensures that ecosystems—such as forests—can thrive—sustaining people, climate and biodiversity for generations to come.'

Jennifer Steinmann
Deloitte Global Sustainability Business Leader, Deloitte

'The *Circularity Gap Report 2025* is a broad scorecard on the state of global circularity and offers a clear roadmap for how to incorporate circular practices into business strategies. It provides leaders with actionable insights on how to invest in diverse material streams and circular pathways in order to enhance supply chain resilience and mitigate risks. By doing so, business leaders can unlock growth and new opportunities for innovation and efficiency across their enterprises.'

Rasmus Abildgaard Kristensen
Ambassador of Denmark to India, Ministry of Foreign Affairs of Denmark

'India is central to the global circular economy transition, with its dynamic industries, innovation ecosystem, and vast potential for circular solutions. The *Circularity Gap Report 2025* provides vital insights to guide this shift, highlighting both the urgency and opportunities of reducing material use while supporting resilience.'

Chris Jansen
Minister for the Environment and Public Transport, Government of the Netherlands

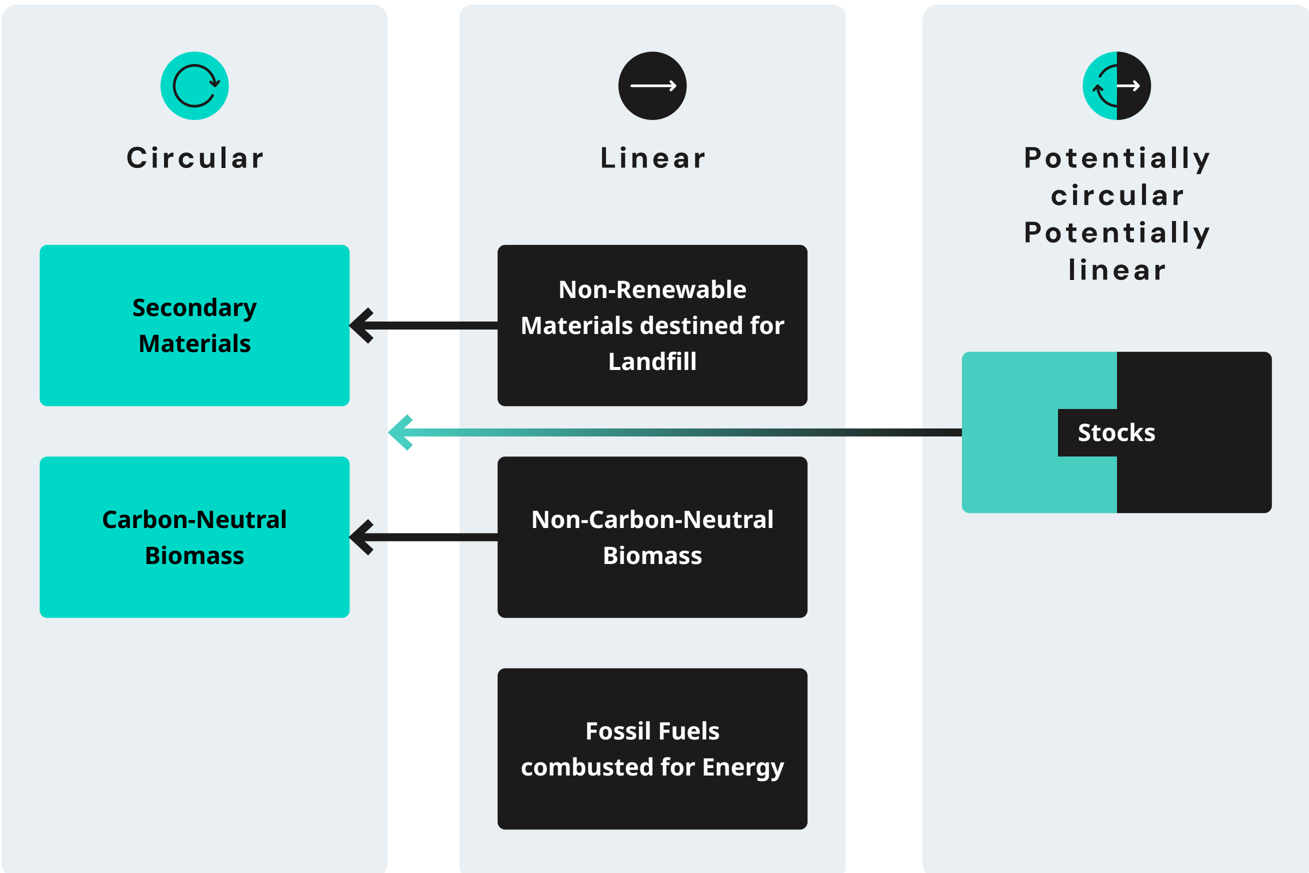
'The annual *Circularity Gap Report* gives an important insight into the relative amounts of recycled materials in our economy. It is therefore a source of inspiration for the Netherlands in shaping effective and realistic circular policies. We can unlock an acceleration towards the circular economy to enhance our competitiveness, reduce strategic vulnerabilities, and create future-proof jobs.'

Executive summary

The economic system should deliver maximum possible wellbeing within the safe limits of our planet. After seven years of reporting, our message remains much the same: in the face of escalating global challenges, the circular economy offers a means to rewire the entrenched linear practices that no longer serve most people or the planet. Since the launch of the first *Circularity Gap Report* in 2018, we've analysed the Circularity Metric to offer insight into the global state of the circular economy transition.[1] This single figure quantifies the share of secondary materials out of total material consumption, serving as a North Star for tracking progress towards the circular transition. But the Metric is one piece of a larger puzzle. That's why, for the first time, this report analyses the Circularity Gap to examine how the rest of the materials flowing into and out of the global economy are contributing to a circular economy—or not. Global material flows can be broken down into three interconnected categories:

- **Circular:** Secondary Materials (the Circularity Metric) and Carbon-Neutral Biomass;
- **Linear:** Non-Carbon-Neutral Biomass, Fossil Fuels combusted for energy, and other Virgin, Non-Renewable Materials destined for landfill;
- **Potentially circular, potentially linear:** Net additions of virgin materials to Stocks—such as buildings, infrastructure, and machinery—that can either be recycled or wasted at their end-of-life many years down the road.

This report examines how materials enter the economy, whether they re-enter it and, if not, how they leave it—either as waste or emissions. Various sub-indicators support each of the headline indicators above to give a sense of where we are, where we're heading, and where targets are needed to drive action in the right direction. This year's report serves as a data-rich, comprehensive report card for the global state of circularity, opening up the Circularity Gap to support practical decision-making.



The Circularity Metric continues to decline: the vast majority of materials entering the economy are virgin, with the share of secondary materials falling from 7.2% to 6.9% as of the latest analysis.

Ongoing declines in circularity can largely be tied to sustained growth in material use. Although the absolute *scale* of secondary material consumption is slowly trending upwards, this is being outpaced by growth in virgin material use. Global extraction has more than tripled in the last fifty years, recently reaching a landmark 100 billion tonnes—and without 'bending the trend', this is set to rise by a further 60% by 2060.[2]

A truly circular economy should be resource-light: without profoundly rewiring systems of production and consumption and applying structural changes across key systems—from housing and food to mobility and manufacturing—we will not be able to close the loop on material consumption. At the same time, there is a significant opportunity to bolster the Circularity Metric by recycling all the materials that potentially *could*[3] be cycled but currently aren't. Virgin, Non-Renewable Materials destined for landfill—including heavy industrial wastes, short-lived consumer products, and end-of-life vehicles or construction materials—account for nearly one-fifth (18.1%) of global material inputs. This represents huge untapped potential: if we were to recycle all waste currently not being recycled *without* reducing overall material use, for example, the Circularity Metric would grow to approximately 25%.

There is potential to boost circularity by better-managing construction and demolition waste, as well as smaller waste streams, like municipal solid waste. However, a good portion of Virgin, Non-Renewable Materials are hard-to-recycle, lower-value waste types, from waste rock to soils, underscoring the importance of rolling out circular strategies that minimise waste from the outset while prioritising high-value reuse and recycling where possible.

The verdict

Without strong global targets to hold us to the right path, we're veering off course for several key indicators. Natural resource management and global material use trends are moving in the wrong direction: material extraction and waste generation are trending upwards, while recycling and controlled disposal rates are both trending downwards over a five-year period. What's more, official, science-based global material use targets are lacking, making it difficult to drive progress.

In an ideal world,

we use as many secondary materials as possible while minimising extraction and consumption. Industries have embraced principles of material efficiency and sufficiency, prioritising the use of recycled inputs alongside circular design principles. Material recovery from long-lived stocks—such as buildings and infrastructure, which can act as 'banks' of materials for reuse—has been optimised. At the same time, countries have vastly improved waste collection, processing and recycling and have minimised waste from extraction processes.

A sustainable bioeconomy is important to the global circular economy transition, but measuring its impact remains a blind spot.

Of all the materials flowing into the global economy, **21.5%** are Carbon-Neutral Biomass, and **2.2%** are Non-Carbon-Neutral Biomass.* Carbon-Neutral Biomass refers to biomass that absorbs as much carbon as it emits over its lifecycle, maintaining a balance through natural processes like regrowth and carbon sequestration.

Non-Carbon-Neutral Biomass represents the portion that exceeds this balance: it doesn't imply a difference in how the biomass is extracted but rather reflects that a certain proportion is 'in the red'. However, all biomass extraction comes with numerous uncaptured environmental impacts. Although renewable, biomass isn't sustainable by default, and carbon neutrality is only a partial criterion for quantifying its circularity. By only considering this aspect, we can't account for the loss of ecological complexity and biodiversity that biomass extraction may cause—for example, large-scale monoculture plantations can deplete soil nutrients, reduce habitat diversity, and contribute to deforestation, threatening ecosystems and species. It is not currently possible to measure other important criteria for circular biomass, such as whether nutrients are safely returned to the biosphere in the right place and at the right rate. For this reason, even Carbon-Neutral Biomass should be considered carefully and with nuance. Though Non-Carbon-Neutral Biomass accounts for just 2.2% of material inputs, it represents approximately one-tenth of total biomass use—still a crucial share to minimise.

Despite its declining share in global material extraction, the scale of biomass extraction has more than doubled in the last half-century, driving land-use change and biodiversity loss and accounting for a significant portion of global emissions. Developing a more circular economy will require a rebalancing of global land use: currently, a disproportionate share of the planet's land is used for agriculture—particularly for pasture and feed crops. Transforming our food systems towards circular, regenerative practices and plant-based, unprocessed diets will be critical to reducing these pressures and restoring ecosystems.

The verdict

We're making some progress, but more must be done to help meet global targets. Global biomass extraction and other key indicators—water stress, for example—are trending upwards, while the share of forested land is decreasing. While we are making progress at safely treating wastewater and bolstering land protection, progress isn't happening at the speed and scope needed to meet global climate and biodiversity targets. Without accelerated action, ecosystems may struggle to sustain the industries and communities that depend on them.

In an ideal world,

we've reduced the land footprint intensity of biomass production and use biomass in a way that respects natural cycles—such as the carbon, nitrogen, phosphorus, and water cycles—prevents the harmful transformation of land, nurtures biodiversity and soil health, and maximises value through cascading where possible.

** A much smaller share of biomass is captured by other indicators, making its way into the technical cycle and contributing to the Circularity Metric, Virgin, Non-Renewable Materials destined for disposal, or Net Additions to Stock.*

Fossil fuel use remains high and continues growing, with few strong incentives to change course.

Although the rate of fossil fuel extraction relative to other materials has declined, absolute extraction has increased—from 6.1 billion tonnes in 1970 to 15.8 billion tonnes in 2021.[4] **13.3%** of materials flowing into the economy are Fossil Fuels combusted for energy, the main driver of climate breakdown. In 2021, energy use accounted for 73%[5] of global greenhouse gas emissions—excluding those from land use, land-use change and forestry—with fossil fuels remaining the dominant energy source today, representing 82% of total primary energy supply.[6]

Historically, fossil fuel demand and global economic growth have been closely coupled—and even now, their use continues to be incentivised through artificially low prices, with explicit subsidies amounting to an estimated US$1.4 trillion in 2021.[7]

The transition to a net-zero energy system presents a major opportunity to reduce reliance on fossil fuels while mitigating environmental harm. To do this, we should systematically restructure how we power transport, generate electricity and process materials. This requires scaling down these activities and reorienting financial flows from subsidies towards decarbonised systems based on electricity and powered by renewable sources. Although the energy transition will initially be material-intensive—particularly in terms of metals—smart system design can reduce reliance on present and future material inputs. This contrasts with the current energy system, which requires a constant flow of fossil fuels to sustain.

Adopting circular design principles—such as durability, reuse, and recycling—at both the product and the system level will be crucial to minimise environmental burden shifting, such as halting fossil fuel extraction but ramping up mining.

The verdict

While there's been some progress towards decarbonisation, it isn't enough to limit warming to 1.5-degrees. Total energy supply and global greenhouse gas emissions are still trending upwards—and while we're seeing positive increases in electrification and renewable energy consumption, we're not yet on track to meet global targets. Electrification, for example, is growing more slowly than energy demand, and the carbon intensity of electricity generation is growing. What's more, half of the waste generated by the global economy is released in the form of emissions: because we can't 'close the loop' on emissions, this represents a significant barrier to bolstering circularity.

In an ideal world,

we've prioritised systemic efficiency to keep growing energy demand in check, enabling renewable energy to replace—rather than simply add to—fossil-based sources in the energy mix. Because electricity is the most efficient and easiest form of energy to decarbonise, we've electrified as many activities and end uses as possible and powered them with clean renewables.

Rapid stock accumulation is a primary driver of rising resource extraction—particularly non-metallic minerals, which account for half of total extraction.

Of all materials entering the global economy, **38%** are virgin Net Additions to Stock. This includes non-metallic minerals, metals, and small amounts of fossil-fuel-based materials and biomass used primarily for buildings, infrastructure, vehicles and machinery.

Stocks aren't inherently positive or negative and even have serious potential to boost circularity down the road if circular design principles are integrated now. By 'mining' existing stocks, we can expand the pool of recyclable materials available to increase the Circularity Metric. However, stocks are highly material-intensive, with their total weight increasing 23-fold over the 20th century,[8] a trend set to continue alongside rapid urbanisation and economic growth.

By 2050, urban populations will grow by 2.5 billion, requiring significant stock build-up,[9] particularly in lower- and middle-income countries. These nations have the opportunity to embed circular principles at scale, avoiding the unsustainable development patterns of higher-income countries by prioritising dense urban environments supported by public and shared mobility options. Meanwhile, higher-income countries with vast existing stocks should minimise new stock growth and focus on extending the lifetim

The verdict

We're using more materials than ever to build up stocks—but targets to guide how and at what rate this is done are lacking across the board. Total floor space, the weight of material stocks and growth in built-up areas are all trending upwards. With a complete lack of global and sub-global targets, we're neither on nor off track—technically speaking. Limiting stock growth—in both incremental and cumulative terms—where it's not necessary and sustainably optimising it through circular design where it is will be essential going forward.

In an ideal world,

circular practices like repair, retrofitting and refurbishing are commonplace ways to keep physical assets in use for as long as possible. Stocks are designed for longevity, and are easy to repair, dismantle and recycle at their end of life—thus providing a flow of valuable secondary materials. Renewable materials, such as sustainably-sourced timber, biocement and biocomposites, contribute to stock composition, and are managed in a circular way. Operations are localised as much as possible to reduce energy consumption for unnecessary transport.

Governments have a key opportunity to lead the circular transition through smart policies and transparent multilateral collaboration. By setting a clear vision and providing unified support for circular initiatives, governments have the critical mandate to shape the right conditions for circularity to flourish—levelling the playing field by shifting tax burdens, reorienting subsidies away from linear activities, and redirecting government funds towards circular projects and initiatives. However, no country can tackle resource use reduction in isolation: transition in our highly globalised world ought to be backed by strong regional—and, where possible, international—collaboration to effectively manage global material flows and reduce extraction. Despite growing recognition of the need to tackle resource mismanagement and align economic activity with our planet's safe limits, this report highlights the lack of both clear targets and a global governance framework to monitor the shift to more sustainable resource use. An international institution on resource management could steer action by providing science-based assessments, policy guidance, and benchmarks to track material use—an approach already reflected in the negotiating text of the legally binding agreement on plastics pollution, for example.[10] At the national level, governments should select and monitor reliable indicators—such as those analysed for this report—to create accountability, identify trends, and refine policies over time, ensuring that circularity efforts have the intended impact.

Businesses that adopt circular practices now can gain a competitive edge, unlock new revenue streams, and future-proof against resource scarcity and market volatility. Although governments set regulatory frameworks, businesses shouldn't wait for these to come into force to begin shaping their new normal. By staying ahead of the regulatory curve and spearheading the transition now, businesses have a lot to gain: they can gain a competitive edge, unlock new revenue streams (through service models, for example), and mitigate risks associated with resource scarcity and geopolitical trade instability. The global economy is facing increasing supply chain disruptions, particularly for the critical raw materials essential to numerous key industries—including the decarbonisation and digitalisation of the global economy. Businesses that integrate circular strategies—including material recovery, closed-loop production, and localised supply chains—can reduce reliance on volatile global markets and potentially cut costs. To maximise these benefits, businesses should consider the bigger picture—such as the indicators measured in this report—whilst simultaneously measuring and monitoring circularity for their own operations and value chains. Communicating progress and the benefits of adopting circular practices can inspire industry-wide adoption, but collaboration is key: by sharing knowledge, practising industrial symbiosis, shifting sales and service models, and working closely with governments, businesses can overcome barriers and build circular economies of scale.

1 Introduction

Ensuring human wellbeing while operating within the safe limits of our planet remains the enduring challenge of our time. The economic system should deliver the maximum possible wellbeing to all while preserving and regenerating the natural environment and ecosystem services underpinning it. The circular economy is a means to this end, with strategies that rethink and optimise how we use resources to provide wellbeing. It can provide the deep cuts in material use needed to stave off climate breakdown, bolster biodiversity, and boost resilience. Calculating baselines is an important step to inspire action and inform target setting—essential for creating accountability, driving international cooperation, steering policy and re-orienting financial flows. This report aims to do just this: building on years of experience calculating the Circularity Metric, it now opens up the Circularity Gap. It recognises that although the Metric has been useful in providing a global baseline for circularity, it is only one piece of a large and complex puzzle. This year's edition provides a comprehensive 'report card' on the state of the global circular economy. It quantifies a dashboard of indicators to ground abstract concepts in reality, spark action, pinpoint where targets are missing, and provide a jumping-off point for decision-makers and advisors across government and industry to take action.

Where we are now and where we’re heading

Over the past eight years of *Circularity Gap Reports* (CGR®), our opening statements have remained much the same: relentless growth in global resource use—driven by the continued expansion of global economic activity—is putting Earth’s systems under extreme pressure. In 2025, the situation is unchanged. The latest *Global Resources Outlook* paints a sobering picture of trends in natural resource use, showing that global material extraction has more than tripled in the last fifty years. We have now surpassed a landmark of 100 billion tonnes of material extraction per year. The global population has not grown at the same rate, showing that this has only played a partial role in spiralling material consumption. Instead, per capita consumption has swelled from 8.4 tonnes in 1970 to 12.2 tonnes in 2020, fuelled by urbanisation, growing GDP and increased affluence. This unfettered growth isn’t set to slow—without deep, systematic changes to the way the global economy operates, material extraction is set to rise by 60% (compared to a 2020 baseline) by 2060.[11]

Although material consumption has been instrumental in raising living standards over the past century, we’ve now passed the point of diminishing returns in many parts of the world. The current scale of global resource use is the main driver of the triple planetary crisis of climate change, biodiversity loss and pollution, with material extraction and use driving around two-thirds of greenhouse gas emissions and over 90% of total biodiversity loss and water stress, for example.[12] As of 2023, we’ve also surpassed six of the nine planetary boundaries vital to life on this planet.[13] Business as usual simply cannot continue if we’re to achieve global climate, biodiversity, and pollution targets and protect and preserve Earth’s life support system.

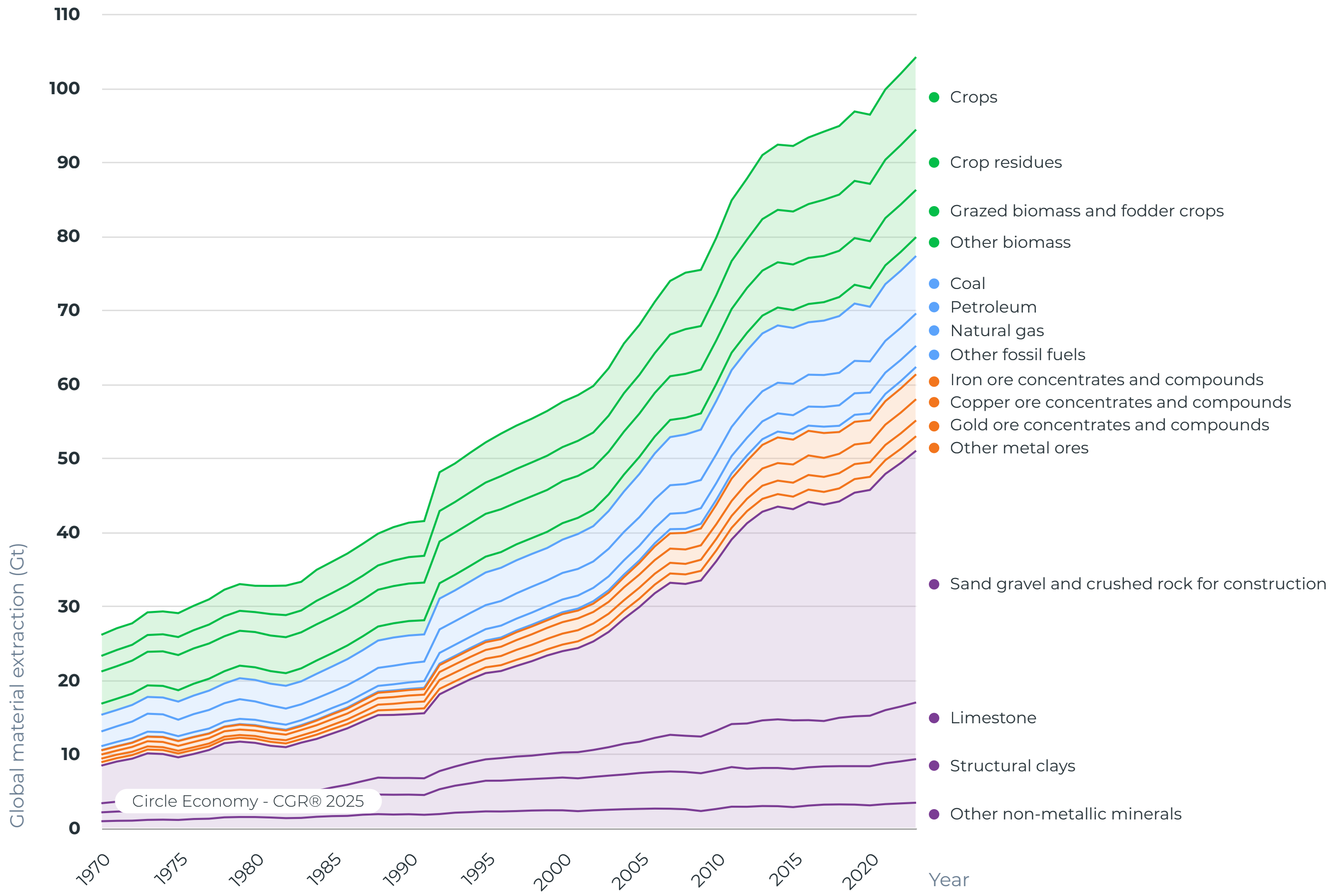


Figure one portrays the evolution of global material extraction from 1970 to 2023 by main material group, as well as the top materials driving this growth.

The widening chasm of resource distribution

Exponential growth in resource consumption hasn't been evenly distributed around the globe: high-income countries have a per capita material footprint six times that of lower-income countries—24 tonnes compared to 4 tonnes.[14] At the same time, high-income countries represent less than one-fifth of the global population, with the EU and US alone consuming more than half the world's materials while housing 10% of the world's population.[15] Much of this material use can be attributed to the build-up of infrastructure and capital equipment, as well as higher consumption among citizens in upper-middle and high-income countries.[16] However, beyond a certain point, increasing material consumption does not necessarily translate to greater well-being: many high-income countries have already reached a saturation point, where further increases in resource use lead to diminishing returns in terms of human development gains (see Figure two). **Striking a balance between resource consumption and human development is crucial.**

At the same time, material consumption has driven environmental degradation in countries with fewer means to mitigate these impacts: per capita, higher-income countries are responsible for ten times the climate impacts of lower-income countries.[17] Lower-income countries bear the brunt of the consequences, with climate-related natural disasters increasing eight-fold in the last decade compared to 1980 levels.[18] Reducing inequality both between and within nations will be key to tackling the triple planetary crisis: in the process of achieving the estimated 'sustainable' level of consumption—8 tonnes per capita—that has served as a benchmark throughout past Circularity Gap analyses, higher-income countries will need to drastically reduce their consumption while lower-income countries can increase consumption to build up necessary service provisioning (renewable energy infrastructure and sustainable housing, for example).[19]

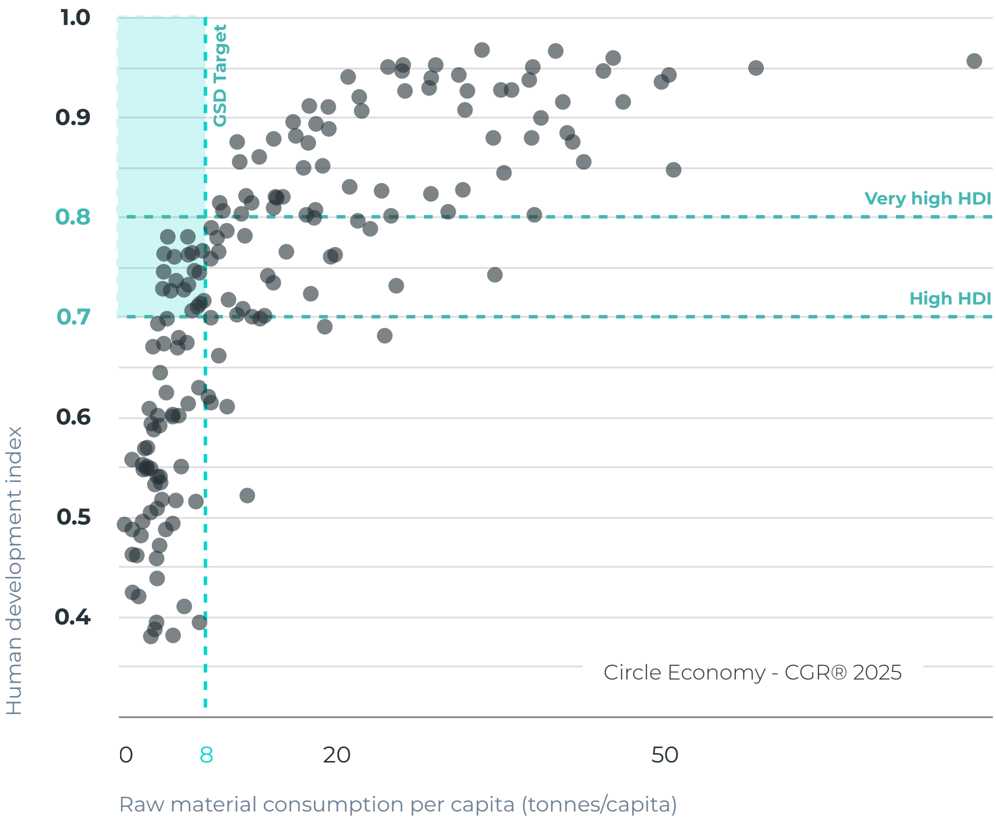


Figure two shows the relationship between raw material consumption per capita (2021) and the Human Development Index (HDI) (2022).

The circular economy as a means to an end

The circular economy, a toolbox of strategies and solutions that rethink and optimise how we consume materials, can deliver wellbeing for all while preserving the environment and ecosystem services that underpin a functioning economy, including clean air, water, natural spaces and biodiversity. Imagine the circular economy as a way to rewire how an economy operates physically: it reduces physical throughputs—and thus environmental impacts—by optimising the transformation of resources into societal needs that contribute to human well-being, such as housing, mobility and nutrition.

We know what the circular economy has to offer: the *Circularity Gap Report 2023* found that we can reverse the overshoot of planetary limits while providing for similar needs with just 70% of the materials we use now.[20] This would mean reducing yearly material consumption to around 8.5 tonnes per capita, approximately equal to the weight of two adult elephants, for example. This is roughly on par with 1970s figures. While this may still seem like quite a lot, it's important to remember that per capita consumption averages include far more than an individual's yearly purchases and take into account the construction of buildings, infrastructure and equipment, just to name a few.

Crucially, the linear economy wasn't created by chance—it was designed. The activities supporting the unsustainable, linear production and consumption patterns driving the mismanagement of natural resources are deeply rooted in our existing system. To successfully transition to a circular economy, we need to change the rules of the game. Fundamentally, this requires a shift in behaviours, norms and belief systems, as well as dismantling the tangled web of laws, regulations and policies that allow for—and often incentivise—boundless extraction, emissions, and waste.

Stakeholders, including governments and businesses, have a crucial role to play in generating momentum for the circular transition and creating the necessary market conditions for industry to shift away from business as usual. This could mean levelling the playing field through regulations, taxes, and subsidies, as well as directly supporting, procuring and advocating for low-carbon, resource-efficient energy technologies, circular and regenerative farming practices, and high-value waste management infrastructure, for example. At the same time, businesses have much to gain by not waiting for regulations to change their practices. By proactively applying circular economy solutions in procurement, product and service design, operations, and waste management, businesses can mitigate resource risks, from supply chain disruptions and price volatility to legislative pressure and reputational risks.[21] What's more, circular products and services allow businesses to increase brand value, increase customer engagement and loyalty, enter new markets, cut costs and stay ahead of the competition in terms of innovation.

Measuring the circular economy

To deliver on the circular economy's potential, we need an effective means to measure how materials are being used at the global level. This provides a solid evidence base for local, national and international changemakers from which to measure and monitor progress. Such oversight is crucial in revealing the true extent and impact of material mismanagement, helping policymakers pinpoint where changes are needed most and helping industries set benchmarks and baselines to start monitoring progress. A more detailed, multifaceted understanding of circularity can bridge gaps between high-level policies and practical, impactful changes across industries, moving us closer to a sustainable, inclusive and regenerative economy. The upcoming **Global Circularity Protocol** for businesses, for example, will play a key role in establishing a shared framework for this effort, ensuring consistency in how circularity is tracked and compared across regions and industries.

We cannot recycle our way out of the current linear economy: regardless of how efficiently we use materials and recycle them at end-of-life, the sheer scale of current material extraction is unsupportable for a healthy and safe planet. This underscores the need to first and foremost focus on the absolute *scales* of extracted materials alongside relative *rates*. As long as extraction continues to increase, incremental improvements in slowing, regenerating and cycling material flows will not be able to offset the significant environmental impacts to come. This principle is illustrated by the Circularity Metric, which has fallen year on year since Circle Economy first began measuring, despite gradual increases in the scale of secondary material use.

Looking at rates—like the Circularity Metric—as opposed to scales alone gives us insight into how quickly resource stocks are depleted and waste is generated, which signals how quickly environmental pressures are building. By monitoring how these rates change over time, we can identify trends in resource efficiency and sufficiency, pinpoint opportunities to decouple wellbeing from material consumption and gauge circular progress. This dual focus on both absolute figures and relative rates is essential to build resilience and shape an environmentally responsible global economy.

The legacy of the global *Circularity Gap Reports*: Updating the circularity metric and expanding our dashboard of indicators

The circular economy agenda has come a long way—particularly regarding monitoring—since the launch of our first *Circularity Gap Report* in 2018. Our Reports have taken a system-wide perspective to monitor and measure the global circular economy. We have historically reported on the Circularity Metric, which measures the proportion of secondary material consumption out of total material consumption for an economy. This is an important indicator for measuring the circular state of an economy. However, this Metric is just one part of a broader picture.

For this reason, the *Circularity Gap Report 2025* aims to **provide a comprehensive report on the state of the global circular economy**, with the view that the Circularity Metric—while important—is only one piece of a large and complex puzzle. This report aims to provide more detail and support practical decision-making by opening up the Circularity 'Gap'.

This report presents and builds on the Circularity Indicator Set, a dashboard of 11 indicators that provide a 'report card' for global material circularity. Collectively, the Indicator Set examines the relationships between resources we take from nature, how we use them, and their impact on the environment. Represented as shares that add up to 100% of material inputs and 100% of outputs such as waste, emissions, and recycled materials, these indicators can be viewed as 'levers' to improve the Circularity Metric. By reducing indicators that capture linear processes—such as disposing of materials without recovery or combusting fossil fuels for energy—we have room for the Metric's share to grow.

The Circularity Indicator Set lends itself well to integration with other leading indicator frameworks for the circular economy: the ISO/DIS standard[22] and the *Conference of European Statisticians Guidelines for Measuring Circular Economy, Part A: Conceptual Framework, Indicators and Measurement Framework*.[23]

This year, the *Circularity Gap Report* provides an expanded report on the state of global circularity. It builds out the Circularity Indicator Set to encompass the beneficial aspects of other leading frameworks and provide further context to the headline indicators. These are elaborated upon through more than 20 other leading indicators—global statistics on waste collection and recycling, energy consumption and land protection, for example. This can help leaders and decision-makers decide where to focus and enact circular solutions that are in alignment with the ultimate goal of improving wellbeing within environmental limits. The result is a cohesive and comprehensive framework suitable for many aims: the headline indicators, for example, are helpful for raising awareness and communicating circular progress at a high level, while lower-tier indicators can provide government officials, policy analysts and other more technical stakeholders with the in-depth information needed to support decision making and agenda setting.

This analysis has a global scope. However, the measurement framework can be set up at the (multi- and sub-)national level to account for trade and the movement of materials between nations for both production and consumption. At the level of businesses and industries, the scope and consequent data collection should be aligned to operations and the relevant aspects of the supply chain, whether regional or multinational.[24] The Circularity Indicator Set can be used as a benchmark and reference if these differences in scope are considered during interpretation.

This year, the *Circularity Gap Report* provides a global benchmark for circularity on a range of dimensions relevant to both governments and businesses. Through this report, governments and businesses can gain an understanding of the global state of circularity and the risks of continuing along a linear path.

2 A report card for the global economy

A comprehensive look into the state of global circularity

The circular economy is a means for delivering wellbeing within planetary boundaries—but how can we take meaningful steps towards dismantling entrenched processes and rewire the way we relate to the material world? This chapter opens up the Circularity Metric (6.9%) and Circularity Gap (the remaining 93.1%), exploring 11 headline indicators and 23 sub-indicators for circularity. It quantifies how materials flow in and out of the global economy and clarifies how various levers can be pulled to boost circularity. The data reveals a troubling truth: progress is underway in some areas, but negative trends are offsetting improvements. Secondary material use, for example, has increased—from 7.1 billion tonnes in 2018 to 7.3 billion tonnes in 2021—but the Circularity Metric continues to fall due to rapid growth in material extraction across the board. At the same time, the scale of Virgin, Non-Renewable Materials disposed of without recovery has risen: these are materials that could contribute to the Circularity Metric but currently aren't. The absolute scale of biomass extraction, fossil fuel use and net additions to stocks have all risen between 2018 and 2021 despite rates remaining relatively stable, underscoring the crucial importance of reducing total material throughput. Although some targets are in place—caps on greenhouse gas emissions and targets for land protection, for example—we need concerted action from businesses and others to cut material use. Currently, we are not on track to meet a single indicator explored in this chapter. This chapter's 'report card' shows that we have yet to get a passing grade. The prognosis is clear: we need strong, science-based targets to generate international momentum towards a circular economy and sustainable resource use.

Understanding material flows: How to interpret the Circularity Indicator Set

Extraction and consumption are growing at almost unprecedented levels, but measuring how and where these material flows are directed can give crucial insight into the circular economy's transformative potential. This chapter opens up the Circularity Gap and gives insight into the global material budget through the Circularity Indicator Set, which measures **Circular material flows** (Secondary Materials and Carbon-Neutral Biomass), **Linear material flows** (Non-Carbon-Neutral Biomass, Virgin, Non-Renewable Materials, and Fossil Fuels used for energy), and **Net stock build-up** (Net Additions to Stock*). Material flows, whether linear or circular, can be broken down into two 'cycles':

- **The technical cycle** relates to the management of non-renewable and largely non-biological resources that are difficult to reintroduce into the biosphere safely. Examples include concrete, plastics and metals, as well as some processed biological materials, such as timber, paper, textiles and bioplastics—this is referred to as 'technical biomass' throughout this chapter. Materials that are part of the technical cycle fall into one of four categories: they become Secondary Materials, are Virgin, Non-Renewable Materials destined for disposal without recovery, are added to Stocks, or are Fossil Fuels combusted for energy.
- **The ecological cycle** relates to the management of renewable, living resources that can cycle in and out of the biosphere. It includes biomass used for feed, food or fuel. Materials in the ecological cycle are either Carbon-Neutral or Non-Carbon-Neutral biomass. As noted, it's important to understand that not all biomass stays within the ecological cycle, with a portion captured by other indicators.

For each indicator, performance is measured on both the **input** side—how materials flow into the economy—and the **output** side—how these materials are processed as waste at their end-of-life. The Circularity Metric, for example, is an input-focused indicator: it measures the share of secondary materials flowing into an economy and thus differs from the global recycling rate, which is an output-focused indicator.

- **Input:** We start with—and give more relevance to—input-side indicators simply because the materials that enter a system ultimately determine what comes out. The moment a material leaves the environment and enters the economy—whether extracted from the earth, harvested, or otherwise sourced—sets the stage for its entire lifecycle. In a manufacturing facility, for example, the types and quantities of raw materials (input) influence the quantities of finished products, as well as the waste and emissions generated from the production process.
- **Output:** Each input-side indicator has a corresponding output. While outputs—like waste, emissions and recycled materials—are directly linked to inputs, there's often a time lag between materials entering and exiting the system. This is because materials take different pathways once they enter the economy: some are **short-lived**—like fuels burnt for energy, fertilisers dissipated into the soil or packaging and consumer goods that are discarded soon after use—and pass through the system rapidly, becoming outputs without significant changes in their resource group composition. Other materials enter the economy and become part of **Accumulated Stocks**—like buildings, infrastructure and vehicles—and remain in use for years. Because past and present material use patterns differ in composition, changes between input- and output-side indicators are largely influenced by the dynamics of stock renewal and depletion. Simply put, the materials flowing out of the economy today are not shaped just by what is entering the economy now but largely by the gradual release of materials from Accumulated Stocks. This highlights the importance of stocks in determining outputs and, ultimately, the circularity of the economy: effective stock management is crucial to maximise circularity and reduce waste over time.

* *The term 'net' is important in the context of stock-flow dynamics. We can distinguish three different types of stock accumulation: **Accumulated Stock**, which measures the total volume of materials added to socioeconomic stocks over time; **Gross Additions to Stock**, which measures the total amount of materials used in long-lived applications (of over one year) in the accounting year. In the context of this analysis, this can include both virgin and secondary materials; and **Net Additions to Stock**, which measures the net amount of materials in long-lived applications after accounting for materials removed from accumulated stocks through Demolition and Discard in the accounting year. This flow only contains virgin materials, as the amount of secondary materials in both Gross Additions to Stock and Demolition and Discard is assumed to be equal within the same accounting year. **This report's analysis measures Net Additions to Stock**.*

On both the input and output sides, indicators are represented as percentages that sum to 100%, and thus, each represents a fraction of how materials enter and leave the economy globally. Values for each headline indicator are provided in Table one and Table two for 2021, the data year for this report, and 2018 to give insight into trends over the last years. These indicators are defined and qualified throughout the remainder of this chapter.

	Indicator	2018		2021	
		Rate (%)	Scale (billion tonnes)	Rate (%)	Scale (billion tonnes)
Circular material flows	Circularity Metric (Input Technical Cycling)	7.2%	7.1	6.9%	7.3
	Carbon-Neutral Biomass (Input Ecological Cycling Potential)	21.6%	21.5	21.5%	22.8
Linear material flows	Non-Carbon-Neutral Biomass (Input Non-Renewable Biomass)	2.6%	2.6	2.2%	2.3
	Other Virgin, Non-Renewable Materials (Input Non-Renewable Flows)	18.0%	17.9	18.1%	19.2
	Fossil Fuels used for energy purposes (Input Non-Circular Flows)	13.9%	13.9	13.3%	14.1
Net stock build-up	Net Additions to Stock	36.7%	36.6	38.0%	40.3

Table one provides values for each headline indicator on the input side for 2018 and 2021, the year of latest available data.[25]

	Indicator	2018		2021	
		Rate (%)	Scale (billion tonnes)	Rate (%)	Scale (billion tonnes)
Circular material flows	Waste destined for recycling (Output Technical Cycling)	11.1%	7.1	11.2%	7.3
	Waste and emissions from Carbon-Neutral Biomass (Output Ecological Cycling Potential)	34.5%	22.1	35.3%	23.2
Linear material flows	Waste and emissions from Non-Carbon-Neutral Biomass (Output Non-Renewable Biomass)	4.1%	2.6	3.4%	2.2
	Waste disposed of without recovery (Output Non-Renewable Flows)	28.3%	18.1	28.6%	18.8
	Emissions and waste from Fossil Fuels used for energy purposes (Output Non-Circular Flows)	22.0%	14.1	21.6%	14.2

Table two provides values for each headline indicator for the output side for 2018 and 2021, the years with the latest available data.[26]

Circularity Indicator Set *of the global economy*

These headline indicators provide a consolidated big-picture overview of the state of circularity, but it's also important to go a layer deeper to provide even more context for what these global, macro-level figures are telling us. This chapter explores relevant sub-indicators for each of the headline indicators listed above, along with insights on their importance and guidance on how these indicators can be interpreted and used to track the transition.

Figure three breaks down the shares of each component of the Circularity Indicator Set for 2021 (the latest available data year), showing how materials enter the economy, are used, and eventually become outputs.

INPUT

Of the **106.1 billion tonnes of processed materials** flowing into the global economy:

- **6.9 %** are Secondary Materials (Technical Cycling rate)
- **21.5 %** are Carbon-Neutral Biomass (Ecological Cycling Potential rate)
- **2.2 %** are Non-Carbon-Neutral Biomass (Non-Renewable Biomass rate)
- **18.1 %** are other Virgin, Non-Renewable Materials (Non-Renewable rate)
- **13.3 %** are Fossil Fuels used for energy purposes (Non-Circular Flows rate)
- **38.0 %** are virgin materials accumulated in Stocks (Net Additions to Stock)

OUTPUT

Of the **65.7 billion tonnes of processed output** flowing out of the global economy:

- **11.2 %** are waste destined for recycling
- **35.3 %** are waste and emissions from Carbon-Neutral Biomass
- **3.4 %** are waste and emissions from Non-Carbon-Neutral Biomass
- **28.6 %** are waste disposed of without recovery
- **21.6 %** are emissions and waste from Fossil Fuels used for energy purposes

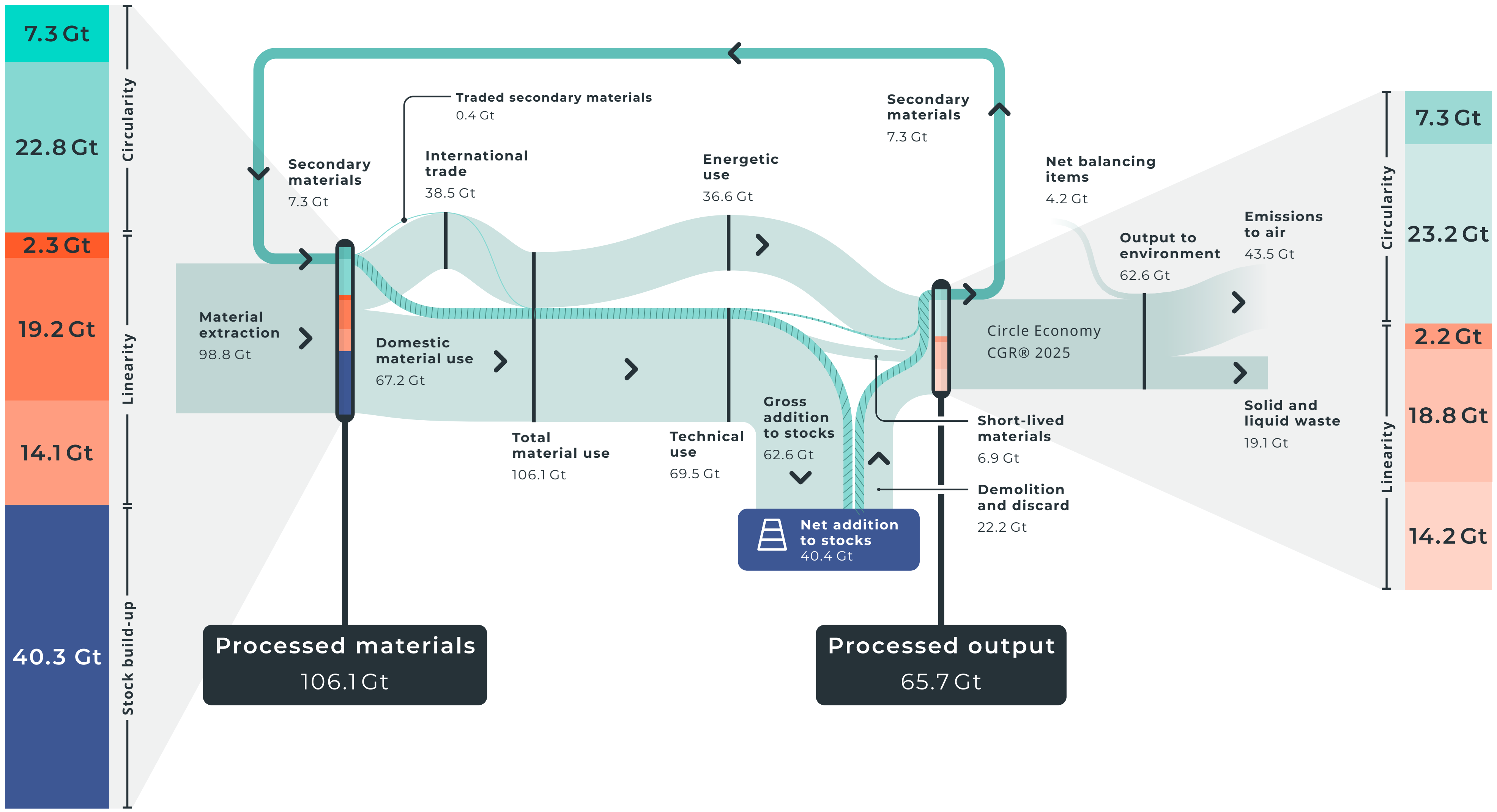


Figure three illustrates the Circularity Indicator Set of the global economy using 2021 data.[27]

2.1 Circular material flows

Circular flows refer to materials that flow through the economy in a way that prioritises reuse, recycling, and regeneration over virgin extraction and waste disposal. The Circularity Indicator Set differentiates between two types of circular flows, technical and ecological, corresponding to **Secondary Materials** and **Carbon-Neutral Biomass**, respectively.

2.1.1 Secondary Materials

Secondary Materials represent the materials collected, processed and recovered from waste for secondary use in an economy, whether global, national or local. These can substitute virgin materials, which are extracted directly from nature. This indicator is quantified on the input and output side:

6.9%

of materials flowing into the economy are...

Secondary Materials—including non-metallic minerals, metals, fossil fuels used for material purposes, and technical biomass—both recycled and downcycled. This share represents the portion of secondary materials out of the total material input of the global economy, which includes all primary and secondary materials.

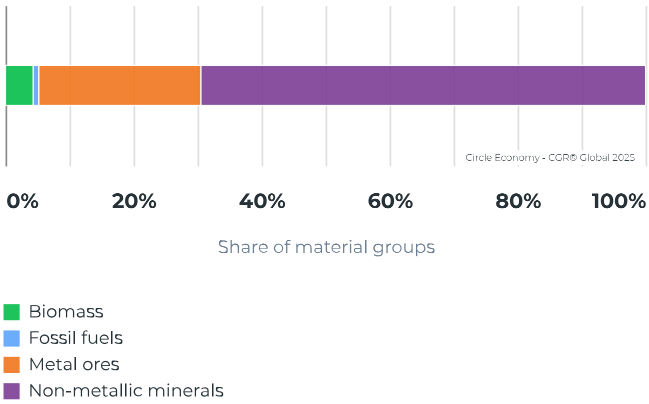
This indicator is referred to as the Circularity Metric.

11.2%

of materials flowing out of the economy are...

Waste destined for recycling.[28]

(Input) Secondary Materials broken down by material group



Desired outcome:

Maximise the use of secondary materials by: 1) Systematically reducing raw material extraction and overall material throughput, 2) Ensuring that recycled and by-product materials become a more mainstream input across all economic sectors, and 3) Prioritising the optimisation of material recovery from Accumulated Stocks such as buildings and infrastructure.

Commentary:

The share of Secondary Materials entering the global economy is low—and steadily falling year on year, from 7.2% in 2018 to 6.9% as of the latest available data (2021). This decline is largely due to sustained growth in overall material use, which outpaces growth in secondary material use. In other words, as long as material consumption keeps rising, completely closing material loops is incompatible with growth in material throughput. We now know the impact of current and unprecedented levels of virgin material use: high greenhouse gas emissions, biodiversity loss and pollution.[29] In fact, our *Circularity Gap Report 2021* found that as much as 70% of global emissions stem from material handling and use.[30] This highlights the need to reduce virgin material use while increasing secondary material use—both of which will drive up the **Circularity Metric**. Achieving this will involve cycling all materials that could be cycled but are not (see page 40) and reducing other linear activities, such as fossil fuel use (see page 44).

Increasing circularity is far more complex than just increasing material cycling. While increasing secondary material use as much as possible is important, there's a natural limit to how much the Circularity Metric can grow. Even if all waste currently not being recycled was recycled—without reducing overall material throughput—we would only reach a Circularity Metric of roughly 25%. This puts our conception of 'circularity' in perspective: true circularity isn't about recovering and recycling more, it requires fundamentally restructuring how we extract, produce and consume materials. The *Circularity Gap Report 2021*, for example, found that rolling out these deep structural changes across key systems—such as housing, food, and mobility—would reduce material use by approximately one-third—shifting us much closer to a sustainable level of material use, estimated at 8 tonnes per capita.[31] This exemplifies the importance of understanding the absolute scale of virgin and secondary material use, alongside rates like the Circularity Metric.

By breaking down current sources of secondary material use, we can better understand opportunities for improvement (see Figure four). Approximately half (49.6%) of the Circularity Metric is composed of recycled **construction and demolition waste**—a heavy waste stream by mass. The built environment can be seen as a huge repository or 'bank' of materials that can be recovered and reused at their end-of-life. However, only 22% of construction and demolition waste is recycled, leaving potential for improvement. What's more, it's likely that a significant portion of 'secondary' construction and demolition materials is represented by aggregates used for low-value applications such as backfilling. **Industrial waste**—comprising metal scrap, sludges, chemical waste, offcuts, and industrial packaging, for example—is a close second, representing 44% of secondary material use. Of all industrial waste generated, approximately 41% re-enters the economy. **Municipal solid waste**—the everyday items we use and then recycle—contributes a much smaller portion, at just 3.8% of the total. It should be noted that global municipal solid waste collection rates average around 80%, but only 15% of the total makes its way back into the cycle—indicating significant potential for improvement. **Special wastes** like healthcare waste, hazardous waste and electronic waste represent just 2.6%.

Boosting secondary material use at a macro level is a complex challenge. What concrete actions are needed to move the needle and ensure more materials make their way back into the cycle? To understand and measure progress towards higher secondary material use, it's important to break down the factors influencing these indicators using a set of sub-indicators for both material inputs and outputs. Table three provides an overview of these indicators, their current status, and whether or not they have relevant global or sub-global targets.

Input: Virgin material use has a significant impact on the Circularity Metric. At a global level, it directly corresponds to **material extraction**, which provides a snapshot of the volume and type of materials extracted from the Earth and signals the extent to which economies depend on them. Global material extraction[32] has more than tripled in the last 50 years, reaching 99.8 billion tonnes in 2021 (see Figure one). As extraction continues to rise, the ability of secondary materials to meaningfully reduce reliance on new extraction is shrinking.

Global secondary material consumption

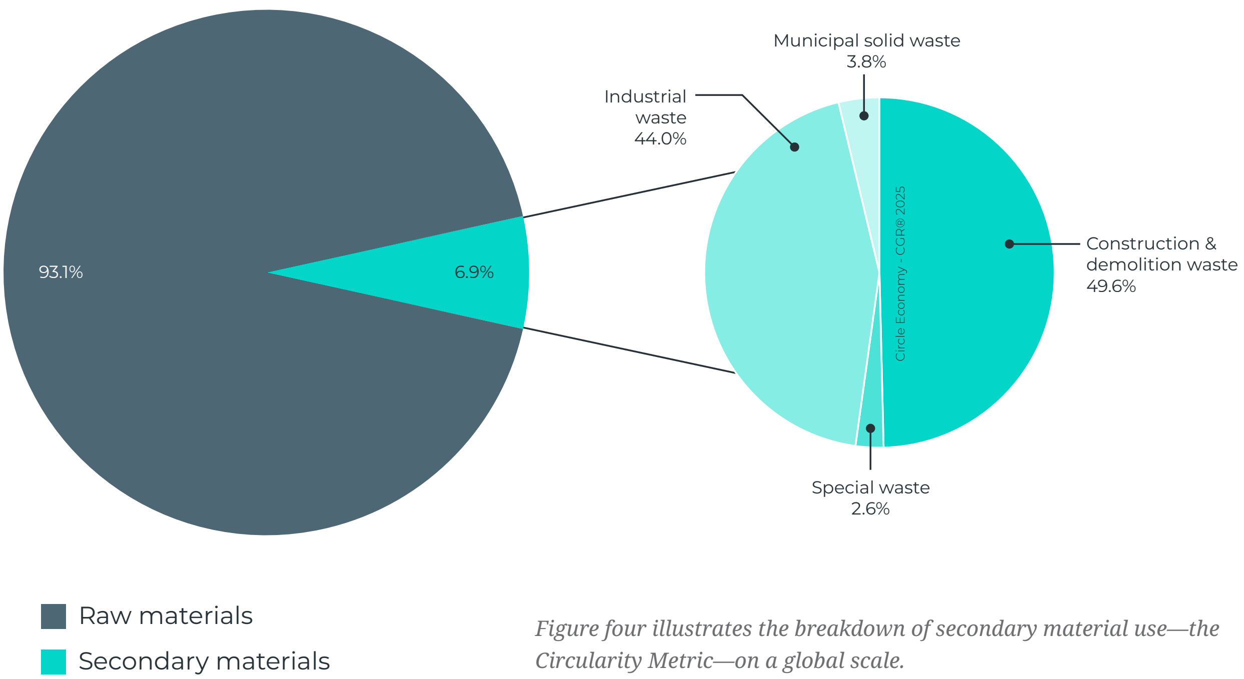


Figure four illustrates the breakdown of secondary material use—the Circularity Metric—on a global scale.

Output: As material use grows, so does **waste generation**, totalling 26.4 billion tonnes globally.[33] While a large part of the materials extracted remain within the economy for years as Accumulated Stocks (see page 23), a share becomes 'output'—in the form of emissions and solid and liquid waste—in a relatively short amount of time. Although minimising waste generation should be the priority, measuring **waste as a share of Processed Outputs**—the materials that leave an economy as either emissions or physical waste—gives insight into which portion of these outputs can be recovered and, ideally, recycled. This share stands at 45.2% globally.[34] A higher share of waste compared to emissions (see page 44) points to a larger pool of resources available for recovery. Optimising how these outputs are dealt with—whether they are sent to landfill, incineration, or recycling, for example—will be key to minimising the share that actually becomes waste. The relatively high **global waste collection rate** (82%) and low **global recycling rate** (27%[35]) shed light on the effectiveness of recycling systems on a global scale, revealing a significant gap between collection and recycling. These figures are important to track as waste must be collected, sorted, processed and recycled to be transformed into secondary materials, which can then re-enter the economy. However, a portion of collected waste is instead directed to controlled or uncontrolled disposal. In countries where waste management infrastructure is still developing, tracking the **controlled disposal rate** (globally 15.6%) will be an important interim step. Strengthening controlled disposal systems can help reduce uncontrolled waste dumping while laying the groundwork for expanding recycling capacity in the future.

Indicator	Value in (year)	Trend	Global Target	Status	Sub-Global Targets (Y/N)
Global material extraction (tonnes)[36]	12.6 tonnes per capita (99.8 billion tonnes) (2021) 12.3 tonnes per capita (95.0 billion tonnes) (2018)	↑	**8 tonnes** per capita per year[37]	Off-track	No
Total waste generation (tonnes)[38]	26.4 billion tonnes (2021) 26.1 billion tonnes (2018)	↑	None	n.a.	Yes
Waste as a share of Processed Outputs (%)[39]	45.2% (2021) 44.6% (2018)	↑	None	n.a.	No
Waste collection rate (%)[40]	82% (various reference years)*	No data**	None	n.a.	Yes
Recycling rate (%)[41]	27.0% (2021) 27.4% (2018)	↓	None	n.a.	Yes, although most countries set recycling rates for specific waste streams rather than overall targets.
Controlled disposal rate (%)[42]	15.6% (2021) 16.0% (2018)	↓	None	n.a.	No

Table three lists each sub-indicator, elaborating on how these figures have changed over a five-year period and whether we are on track to meet global targets (if any).

** Based on the latest available data from each country.*

*** Data gaps make it difficult to provide a coherent trend.*

2.1.2 Carbon-Neutral Biomass

This indicator concerns biomass used for food, feed, and fuel, such as food crops, agricultural residues or wood. It does not include certain biomass flows like timber used for building up stock, or packaging applications, for example. There are four criteria for biomass to be considered circular, described in depth on page 32.[43] Circular biomass must:

1. **Minimise environmental impact:** Assess and reduce the impact of biomass extraction on ecosystem services.
2. **Ensure renewability and regeneration:** Use biological materials in a way that respects their natural renewal rates and prioritise regenerative practices that lead to improved outcomes (afforestation and rewilding, for example).
3. **Cascade use:** Reuse bio-based products and cascade materials before discarding them.
4. **Close the nutrient cycle:** Ensure nutrients return safely to the biosphere at their end-of-life.

Measuring the circularity of 'technical' materials is easier than that of biological materials, as they are processed and reused within industrial systems. While biological materials do flow into the industrial system, their circularity broadly relates to how they're returned to the natural system and the health of the broader ecosystem that they belong to. This is not always concretely defined nor easily measured.

Because determining the circularity of biological materials is conceptually complex and difficult to measure,[44] this indicator captures biomass that meets the minimum criterion of carbon neutrality, meaning it absorbs as much carbon during its growth as it emits when used. This partially addresses the first and last criteria listed above. While some biomass captured by this indicator may meet some or even all of the remaining criteria, measuring or guaranteeing this is not possible due to data limitations. Biomass that meets none of the criteria is measured by another indicator: Non-Carbon-Neutral Biomass.

All biomass that stays within the ecological cycle falls into two categories: carbon-neutral and non-carbon-neutral. Carbon-Neutral Biomass meets certain criteria to be considered carbon neutral, while Non-Carbon-Neutral Biomass exceeds these limits and is considered 'in the red'. This distinction between the two doesn't relate to how the biomass is extracted, but just that a portion is in excess. For more information on Non-Carbon-Neutral Biomass, skip to page 37.

This indicator is quantified on the input and output side:

21.5%

of materials flowing into the economy are...

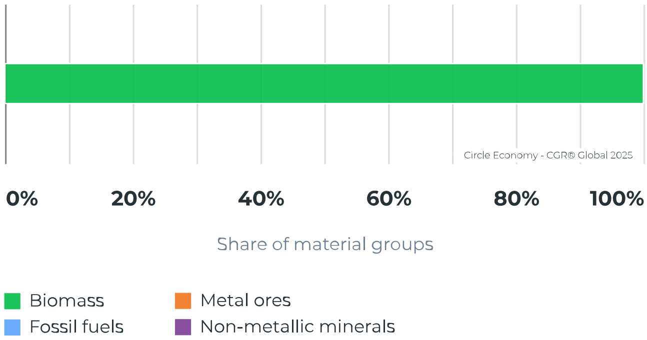
Carbon-Neutral Biomass. This figure quantifies the share of renewable primary biomass inputs in processed materials.

35.3%

of materials flowing out of the economy are...

Waste and emissions from Carbon-Neutral Biomass.

(Input) Carbon-Neutral Biomass broken down by material group



Desired outcome:

Transition to exclusively using biomass that:
1) Respects natural cycles—such as the carbon, nitrogen and water cycles—and ensures carbon neutrality and full nutrient cycling in the right place and at the right pace; 2) Prevents land degradation to preserve and enhance complex, biodiverse ecosystems with healthy soils, and 3) Maximises its value through cascading where possible: reusing it multiple times, through multiple stages, before it is eventually discarded.

Measuring the circularity of biomass

Current circular economy monitoring systems are largely designed to track and interpret technical cycles and focus on the reuse of materials within this sphere. However, this approach means that it's difficult to monitor and capture circular economy potential fully, as the circularity of biomass is not adequately captured. Biomass is not inherently circular, and the ecological costs of its (over)extraction, from land-use change and the disruption of nutrient cycles to habitat and biodiversity loss, can no longer be overlooked. To be fully circular, biomass must:

1. **Minimise environmental impact:** This means assessing and reducing the impact of resource extraction on ecosystem services—the benefits nature provides to humans, including clean air and water, climate regulation, and natural resources—including those resulting from land-use change and resource depletion. It also involves accounting for the carbon balance by tracking biogenic carbon flows—sequestration, storage, and release—and their impact on the global climate. These flows differ from fossil carbon in that they cycle through the atmosphere over much shorter timescales.
2. **Ensure renewability and regeneration:** This means using biological resources in a way that, at the very least, respects their natural renewal rate, prioritising sustainable sourcing to maintain long-term availability. This includes recognising that old, wild ecosystems—such as mature forests—provide far greater biodiversity, carbon sequestration, and ecosystem stability compared to new plantations. Preserving and sustainably managing natural ecosystems is critical to maintaining these unique and irreplaceable benefits.
3. **Optimise cascading use:** This means maximising the value of biological resources[45] by identifying pathways for their multiple uses and streams, ensuring resources are reused effectively before they reach their end-of-life. For example, agricultural residues can first be used for materials such as bioplastics or paper, then as animal bedding or compost, and finally for bioenergy.
4. **Close the nutrient cycle:** This means that biological materials can biodegrade and safely return to the biosphere at their end-of-life. This involves improving material separability and biodegradability, minimising harmful substances in emissions to the environment and returning nutrients to the ecosystem in a place and at a rate that supports regeneration. 'In place' refers to the principle that nutrients should be returned to the place in an ecosystem where they are needed to sustain biological processes rather than deposited where they could cause harm—for example, eutrophication in water bodies. 'At rate' refers to the principle that nutrient cycling should align with an ecosystem's natural regenerative capacity, being reintroduced at a pace that an ecosystem can absorb, process and use without being disrupted. Note that 'nutrients' here refer to nitrogen, phosphorus, sulphur, carbon and water.

Due to methodological constraints and current data availability, it is not possible to assess all of these criteria. This is why Ecological Cycling Potential takes **carbon neutrality** as a minimum criterion, which partially addresses the first and fourth criteria listed in this box. This approach considers land use, land-use change and forestry emissions to determine which changes in ecosystem carbon stocks result from biomass extraction. This is a minimal requirement but an incomplete one: consider, for example, a sustainably managed forest where trees are replanted to replace those harvested. These activities may be carbon neutral, but only considering this aspect does not account for the loss of the ecological complexity and biodiversity that are hallmarks of old-growth forests. Managed forests may be monocultures or have a limited number of species, making them less resilient and valuable—even if they're carbon neutral.

Commentary:

There are no established methodologies for reliably measuring the circularity of biomass use, but considering the carbon balance of biomass use is a first step. This indicator considers biomass that is carbon neutral as a minimum criterion for measuring its circularity. While a rate of 21.5% may seem positive, biomass extraction remains synonymous with a number of uncaptured negative environmental impacts. Because of this, a more circular and sustainable world would not necessarily result in an increase in the rate or scale of Carbon-Neutral Biomass extraction. Regardless of whether this indicator grows or shrinks, it's crucial that all materials captured by it undergo full nutrient cycling: as discussed, this important criterion is not aptly reflected. In the future, identifying certification labels that rigorously assess all four criteria—as defined on pages 30 and 32—could be a practical approach to calculating the share of circular biomass.

The scale of biomass extraction is high and a key driver of environmental impacts. Despite its declining share in global material extraction (from 41% in 1970 to 26% in 2021), in absolute terms, biomass extraction has more than doubled in the past 50 years, increasing from 10.8 billion tonnes in 1970 to 26.3 billion tonnes in 2021 (see Figure five). Within this context—and contrary to common assumptions—biomass extraction and use is a significant driver of environmental impacts. It's among the largest contributors of greenhouse gas emissions, representing 18% of the total—largely linked to food and feed production—while clearing land for crops is a key driver of habitat destruction and accounts for over 90% of land-use-related biodiversity loss.[46] Many of these impacts are driven by global food systems, with food and feed production accounting for 79% of the global biomass demand considered under this indicator and Non-Carbon-Neutral biomass (see page 37).[47] A further 12% is represented by fuel, and 9% is represented by other uses, such as straw.

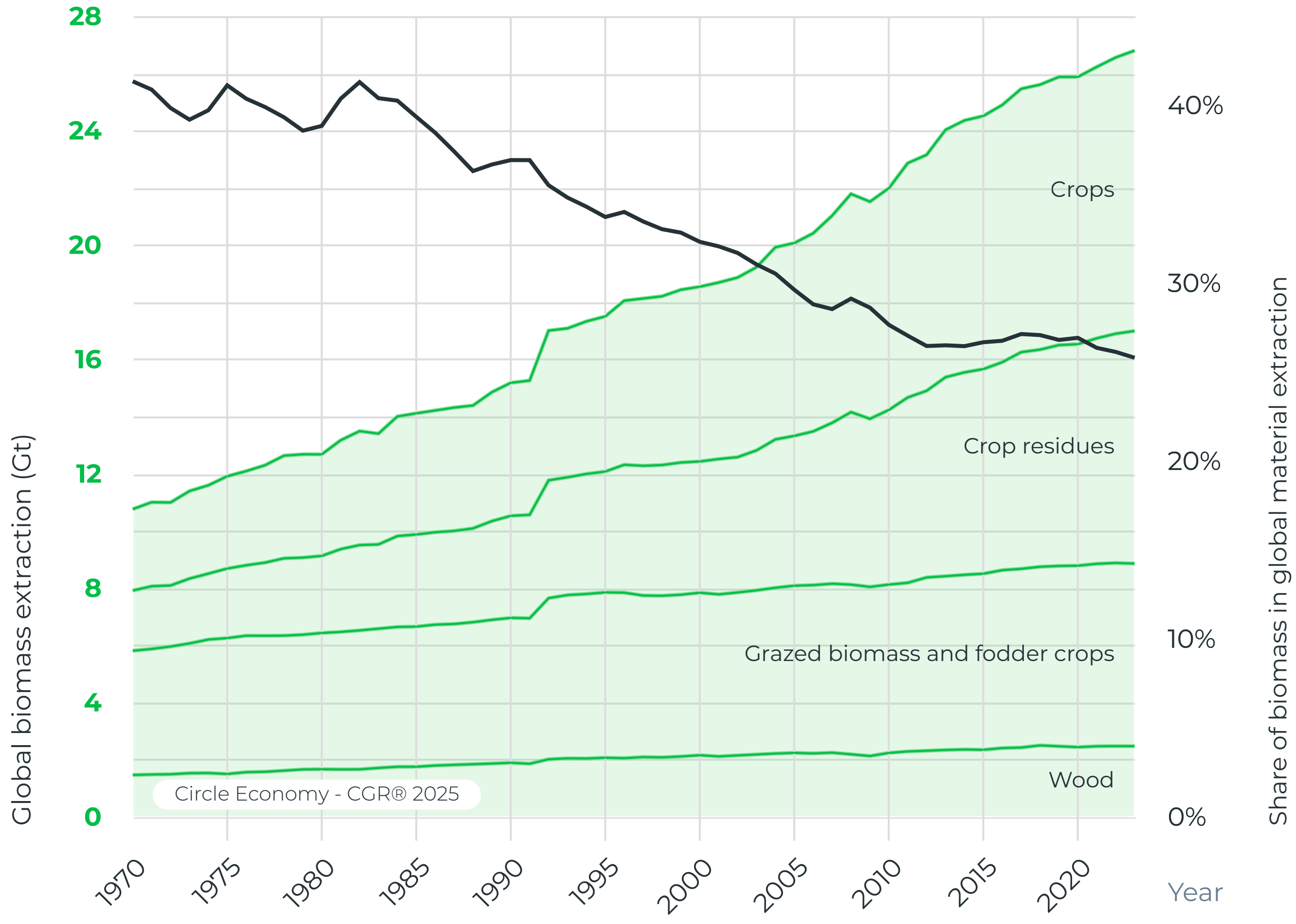


Figure five illustrates the evolution of global biomass extraction and its share of total material extraction between 1970 and 2021.

Developing a more sustainable and circular global economy requires transforming land use and agriculture. A disproportionate fraction of global land is used intensively, primarily for agricultural purposes such as pasture and animal feed production:[48] half the world's habitable land is used for agriculture, with 80% of this dedicated to livestock. Despite the space required to rear livestock and grow feed crops, livestock provides only a fraction of the global calorie supply.[49] On a planet with limited space, this inefficiency has significant consequences. As agricultural land continues to expand—often encroaching on forests, wetlands and other wild ecosystems—we continue to witness a severe retreat of nature. This is the main cause of land use and land-use change emissions through deforestation, as well as biodiversity loss and soil degradation.[50] At the same time, we waste about one-third of all food produced, contributing as much as 10% of global emissions.[51] This means valuable land is used for food that never gets consumed—land that could instead contribute to carbon sequestration and biodiversity. To rebalance global land use, we need to redesign the food system into a holistic, circular and regenerative system that safeguards planetary and human health.[52] Leveraging a sustainable global food system's full potential requires transforming both production and consumption patterns. This includes minimising synthetic fertilisers that pollute soil and water, prioritising regenerative practices like agroforestry and integrated livestock systems, and promoting nourishing diets with more plant-based foods and fewer ultra-processed products.[53,54] These practices can decrease demand for land and other resources, such as water, freeing up space for rewilding and reforestation, helping restore damaged ecosystems, expanding global carbon sinks, and allowing biodiversity to flourish. It will also build up the resilience of food production and improve food security in many countries and regions.

Building a sustainable, circular bioeconomy is essential for advancing sustainable resource use, but there is no harmonised methodology to measure and monitor it. Measuring the rate of Carbon-Neutral Biomass is also important to monitor the sustainability and circularity of the bioeconomy, which covers all sectors and activities that rely on biological resources (animals, plants, microorganisms and derived biomass, including organic waste) and their ecological functions.[55] A 'circular bioeconomy' is an economic model that combines the principles of both the circular economy and the bioeconomy and aims to optimise the use of renewable biological resources while minimising waste and environmental impact through circular practices.

To understand and measure progress towards a more circular bioeconomy, it is therefore important to break down the factors influencing these indicators through a number of sub-indicators. These indicators' status—and whether or not they have relevant global or sub-global targets—is summarised in Table four.

Input: **Global biomass extraction** is a key driver of environmental impacts: its scale is crucial to track. In 2021, this indicator stood at 26.3 billion tonnes, equivalent to 3.3 tonnes per capita.[56] Various biomass materials and farming practices have different associated impacts: livestock systems, for example, have much higher material, carbon and land footprints than crops cultivated for direct human use.[57] This is why measuring extraction indicators by **biomass type and activity** can help indicate where the most impact can be made. **Water stress**—which measures the share of total human water withdrawals relative to available freshwater resources—provides important insight into the sustainability of biomass production, especially in water-scarce regions.[58] Globally, water stress is 18.6%, but levels vary substantially by region. Central and Southern Asia have high water stress levels—surpassing 75%—while Northern Africa's water stress exceeds 100%, requiring groundwater depletion or desalination, for example. In 2020, 2.4 billion people lived in water-stressed countries.[59] Measuring water requirements alongside biomass types and activities can ensure that land use and biomass extraction align with hydrological cycles, allowing water resources to be regenerated.[60] Sustainably optimising biomass use requires regenerative agriculture, better water management, and shifting demand away from resource-intensive products such as meat and dairy. This is especially important given that agriculture is a key driver of water stress, accounting for 72% of global freshwater withdrawals.[61]

At the same time, positive indicators, such as the **share of forested land** (31.1%) (bolstered by **land protection rates**), are essential to show where and to what extent progress is being made. In 2021, forested areas (including non-natural forests) represented nearly one-third of global land area, down from 32.5% in 1990.[62] The average forest area per person has decreased from 1.4 hectares in 1960 to about 0.5 hectares as of 2019, reflecting both population growth and forest loss.[63] Similarly, tracking the **reclamation rate of organic substances** can play a crucial role in enhancing the circularity of global biomass inputs by ensuring that organic waste—like food scraps, agricultural residues, manure, and biodegradable products—is effectively reintegrated into the biological cycle. This indicator is key for monitoring full nutrient cycling, a key criterion for 'circular' biomass. However, no global data on this indicator is available.

Output: On the output side, measuring global **emissions from land use, land-use change and forestry (LULUCF)** captures the impact of activities like deforestation, the draining of peatlands, and the expansion of agricultural land, livestock pastures and human settlements. These activities deplete potential carbon storage and destroy natural habitats, damaging biodiversity. Global net LULUCF emissions account for roughly 2 (between 1.3[64] and 2.7[65]) billion tonnes of CO_2e, or about 5% of total anthropogenic emissions, a significant share of which stems from deforestation.[66] Although carbon sequestration has the potential to offset fossil-based emissions through natural ecological processes, LULUCF currently acts as a net source of global emissions. Better land management thus holds significant potential to capture and reduce emissions, with preserving and regenerating natural carbon sinks essential to limiting warming to 1.5-degrees. Safeguarding and restoring natural ecosystems offers numerous benefits in addition to carbon sequestration—bolstering biodiversity, for example.

It's also crucial to understand the impact of nutrients used for agricultural practices (in fertilisers, for example), which often end up in water systems, by measuring **safely treated wastewater flows**[67] (not available at the global level). Properly treated wastewater supports nutrient recycling, enabling the recovery of nutrients essential to agriculture: nitrogen and phosphorus. This reduces reliance on synthetic fertilisers and promotes the circular use of nutrients in the biological cycle. Proper wastewater treatment can also contribute to broader environmental goals. For example, organic matter recovered from wastewater can be used to generate biogas or nourish soils while treatment processes prevent the runoff of nitrogen and phosphorus in water bodies, where they can cause harm (eutrophication, for example).

Indicator	Value in (year)	Trend	Global Target	Status	Sub-Global Targets (Y/N)
Global biomass extraction (tonnes per capita)[68]	3.3 tonnes per capita (26.3 billion tonnes) (2021) 3.3 tonnes per capita (25.7 billion tonnes) (2018)	Stable (per capita)	**2 tonnes** per capita per year[69]	Off-track	Yes
Water stress (%)[70]	18.6% (2021) 18.3% (2018)	↑	None	n.a.	Yes
Share of forested land (%)[71]	31.1% (2020)* 31.2% (2018)	↓	**33.7%**[72]	Off-track	Yes
Land protection rate (%)[73, 74]	17.6% (2024) 16.6% (2020)	↑	**30%**[75]	Off-track	Yes
Reclamation rate of organic substances (%)	No data	No data	None**	n.a.	No
Emissions from LULUCF (tonnes of CO_2e)[76]	1.3–2.6 billion tonnes (2021)***	No data	None	n.a.	None
Safely treated wastewater flows (%)	Not available at the global level	No data	**60%**[77]	n.a.	Yes

Table four lists each sub-indicator, elaborating on how these figures have changed over a five-year period and whether we are on track to meet global targets (if any).

** Latest available data.*

*** Overall reclamation and recycling rates for organic waste are typically lacking and targets tend to focus on food waste reduction.*

**** LULUCF data is uncertain and fluctuating, making it difficult to determine an accurate trend.*

2.2 Linear material flows

Linear flows make up the Circularity Gap: they're materials that follow a take-make-dispose model and aren't cycled back into either technical or ecological systems. This category comprises three indicators: **Non-Carbon-Neutral Biomass, other Virgin, Non-Renewable Materials** (materials that *could* be recycled but currently are not), and **Fossil Fuels used for energy** (these are combusted into the atmosphere and thus do not have the potential for cycling, making them inherently non-circular).

2.2.1 Non-Carbon-Neutral Biomass

This indicator captures the share of virgin Non-Carbon-Neutral Biomass—including, for instance, crops on the input side and manure and agricultural residues on the output side—out of total resource use. This means that extracting and using this biomass resulted in net positive emissions due to land use and land cover change.

2.2%

of materials flowing into the economy are...

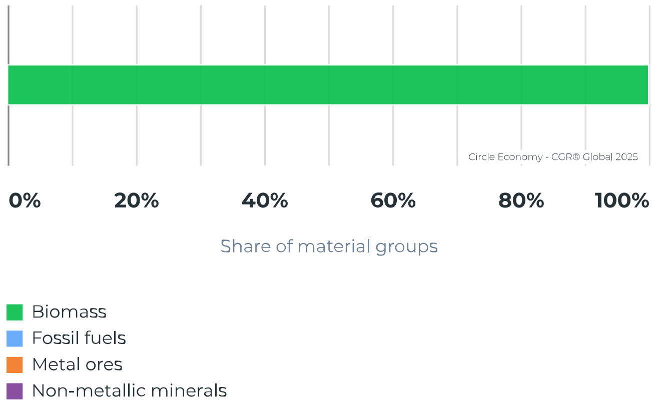
Non-Carbon-Neutral Biomass.
This figure quantifies the share of non-renewable virgin biomass inputs in processed materials.

3.4%

of materials flowing out of the economy are...

Waste and emissions from Non-Carbon-Neutral Biomass.

(Input) Non-Carbon-Neutral Biomass broken down by material group



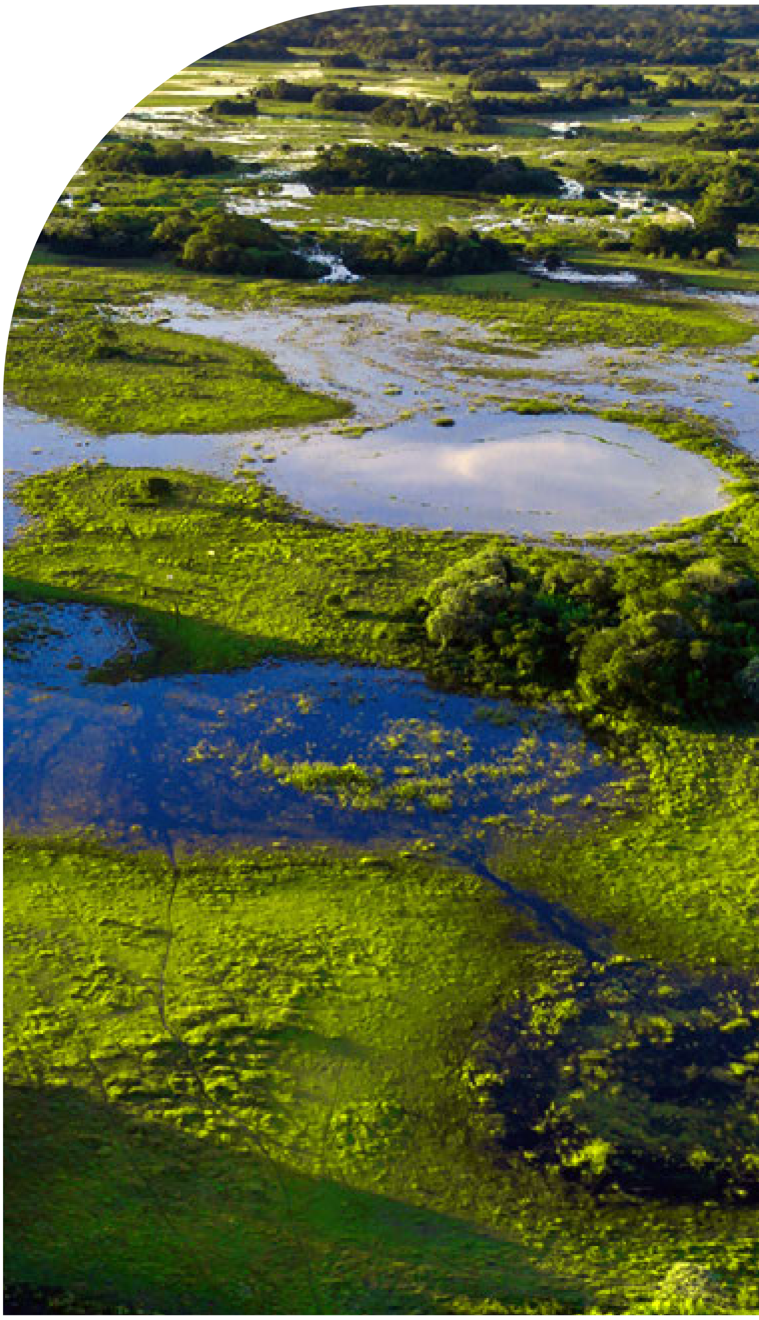
Desired outcome:

Eliminate the use of biomass that:
1) Surpasses the natural rate of regeneration or leads to net positive carbon emissions due to land use change,
2) Disrupts ecological timescales and existing carbon and nutrient balances.

Commentary:

This indicator represents biomass that does not meet the minimum criterion of carbon neutrality. This non-carbon-neutral portion is not linked to a specific source or process but rather represents systemic inefficiencies in biomass extraction. This indicator captures the portion of biomass harvested at a **rate** that cannot be sustainably regenerated or taken from a **place** that disrupts natural ecological balances (input) or that is not returned to the environment 'in place' and 'at rate' (output). The presence of hazardous substances must also be accounted for on both the input and output side. This could include chemicals used to harvest or process biomass, for example, as well as the discharge of contaminated biomass into the environment.

Excessive extraction rates and unsustainable practices make biomass a non-renewable, and thus linear, resource. Harvesting biomass at a rate that exceeds its natural capacity for regeneration essentially makes it a finite, rather than renewable, resource.[78] If biomass is harvested faster than it can regrow or reabsorb the same amount of carbon, it is no longer carbon neutral because the total carbon stock declines. The same applies to soil, another rapidly degrading key renewable resource strongly linked to biomass extraction.[79] For this reason, understanding the climate impact of biomass use means understanding the time-explicit nature of carbon flows: the rate at which carbon is sequestered, how long it's stored, and how quickly it's released back into the atmosphere.[80, 81, 82] Non-Carbon-Neutral Biomass is that which results in emissions from land use and land-cover change through activities that drive deforestation—particularly in tropical forests[83]—and forest degradation and land conversion for agriculture, for example. This could include forest biomass harvesting for large-scale bioenergy production and practices like shifting cultivation, where plots of land are temporarily converted for agriculture and then abandoned and are unable to be fully restored. The drainage and excavation of peat for agricultural purposes also contribute to emissions. Although peatlands represent just 3% of the world's land area,[84] they store vast amounts of carbon, and disrupting them releases large volumes of methane, the most potent greenhouse gas.[85]



Although the current share of Non-Carbon-Neutral Biomass use is small, it needs to be reduced to zero. At just 2.2%, the share of Non-Carbon-Neutral Biomass accounts for a small portion of total material consumption. However, Non-Carbon-Neutral Biomass represents approximately one-tenth of total biomass use, a share that is still crucial to minimise. In fact, this figure may also be higher than estimated, as various studies have demonstrated that different accounting methods can significantly affect the share of biomass considered carbon neutral.[86, 87] For example, the Kyoto Protocol's guidelines for national accounting—used by many countries—have been criticised for allowing countries to adjust forest management definitions to their advantage, leading to underreported emissions.[88] As discussed in the Carbon-Neutral Biomass section on page 30, carbon neutrality is just one of many concerns linked to biomass extraction. Biomass production can also lead to additional environmental risks, including disruptions to natural nutrient cycles. For example, excessive nitrogen and phosphorus can be introduced into agricultural systems, and nutrients from the soil can be depleted through erosion and runoff. The overuse of non-renewable water resources—where water is taken faster than it can be replenished—is also a significant concern linked to biomass harvesting. Five of nine planetary boundaries have a direct link to the bioeconomy,[89] with biomass extraction linked to the overexploitation of forest resources, land use change, biodiversity loss, and increased competition for land from fuel, feed and food.

Non-Carbon-Neutral Biomass shares the same sub-indicators as Carbon-Neutral Biomass: global biomass extraction, biomass types and activities, afforestation and land protection rates, ecological overshoot, level of water stress, average recycling/reclamation of organic substances rates, and proportion of safely treated domestic wastewater flows.

2.2.2 Virgin, Non-Renewable Materials

This indicator measures materials that potentially can be cycled but are not. These are heavy mining and industrial wastes, products that are short-lived (such as paper, packaging, chemicals and some consumer products, including fossil fuels used for material purposes) and longer-lived products reaching their end-of-life (such as discarded appliances, vehicles, or construction materials). Products and materials captured by this indicator will become waste within the year measured. This indicator does not capture fossil fuels used for energy nor biological materials such as food, feed and biofuels, but does represent a small fraction of unsustainably managed renewable resources, such as discarded timber from Accumulated Stocks or wood used for short-lived packaging applications.

18.1%

of materials flowing into the economy are...

Other virgin, mostly Non-Renewable Materials, including non-metallic minerals, metals, fossil fuels used for material purposes, and very small amounts of technical biomass destined for disposal. Materials in this flow are finite resources extracted from the environment in the current as well as previous accounting years, and are disposed of without recovery in the current accounting year.*

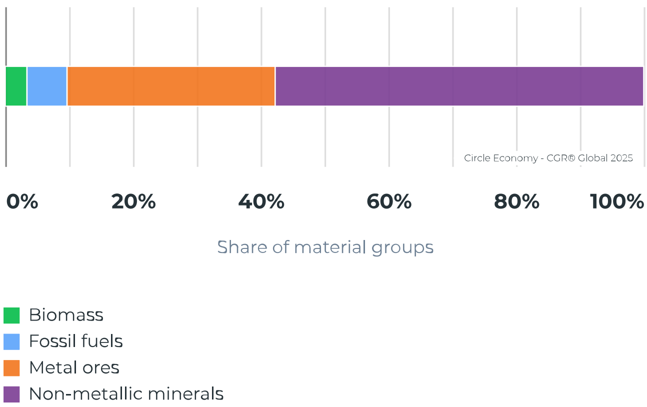
* *To capture the time lag in stock dynamics in a snapshot of a single year, our framework considers Gross Additions to Stock (on the input side) to be equal to Net Additions to Stock plus demolished and discarded materials. In this context, Demolition and Discard refers to materials extracted from the environment and added to stocks in previous years that become waste in the current year. This approach is more useful for circularity measurement than just reporting Gross Additions to Stock on the input side, as it allows us to better understand this portion of inflows from a circularity perspective.*

28.6%

of materials flowing out of the economy are...

Waste disposed of without recovery within the accounting year. This includes waste from both short- and long-lived applications in Accumulated Stocks.

(Input) Virgin, Non-Renewable Materials broken down by material group



Desired outcome:

Minimise all non-renewable material flows and transform how materials are managed throughout their lifecycle by: 1) Prioritising circular strategies that design out waste and reducing waste from extraction as much as possible, 2) Recovering the highest value materials from products at their end-of-life, 3) Eliminating the need for and providing alternatives to fossil-based feedstocks, and 4) Improving collection and recycling systems for all recyclable materials.

This indicator primarily reflects heavy, hard-to-recycle waste, underscoring the importance of circular strategies that minimise waste from the outset. HWhile we don't have a granular breakdown of the materials and products captured by this indicator, we can see that a majority on the input side is represented by construction minerals (53%), with metal ores (33%), industrial minerals (5%), fossil fuels (6%)[90] and biomass (3%) contributing smaller shares. While a portion of the 86% represented by construction minerals and metal ores could be waste from construction and demolition—a very heavy waste stream by weight—the bulk of it likely comprises waste from used and unused extraction from mining and quarrying, for example, including waste rock, tailings and soils.[91] Much of this wouldn't be suitable for high-value recycling, and options to repurpose these materials are limited, often depending on material composition and economic feasibility.

Commentary:

This indicator reveals significant potential to bolster Secondary Material use. This indicator can be interpreted as the antithesis of the Circularity Metric: it includes everything that *could* be contributing to Secondary Material use but isn't. At 18.1% and 28.6%, the input and output rates of Virgin, Non-Renewable Materials reveal substantial room for increasing global circularity. Ideally, the rate of this indicator would fall as close to zero as possible, with these materials instead contributing to Secondary Material use. The absolute scale of Virgin, Non-Renewable Materials should also drop: this indicator grew from approximately 17.9 billion tonnes in 2018 to 19.2 billion tonnes in 2021. Reducing this indicator on the input side will require cutting consumption to prevent difficult-to-manage wastes in the first place, alongside circular design strategies that minimise waste generation and allow for material recovery. On the output side, the emphasis should be on increasing high-value applications for waste and improving waste management infrastructure. For example, when dealing with construction waste, disassembly and reuse are preferable to recycling and highly preferable to backfilling, a low-value application. However, a large portion of materials captured by this indicator are heavy, lower-value waste streams—soils, for example—without higher-value applications.

Waste rock can be crushed and used as aggregate for various construction projects, while tailings can sometimes be used to produce brick and tile. However, many mining byproducts can contain heavy metals or hazardous substances that make them difficult to cycle without extensive treatment, which is costly and poses additional environmental risks. This underscores the importance of reducing material demand and improving processes to reduce the generation of these hard-to-manage wastes in the first place.

While heavy waste streams do make up the majority of Virgin, Non-Renewable Materials, this should not overshadow the importance of better managing smaller waste streams, such as municipal solid waste. It's estimated that the world generates more than 2 billion tonnes of municipal solid waste yearly—a figure set to increase by 70% by 2050.[92] In many parts of the world, the informal sector plays a vital role in municipal waste management, though this often means that these activities aren't properly captured by official statistics nor recognised and supported by waste management policy. Better managing this waste and diverting it from landfills—alongside other damaging waste streams like medical and e-waste—will still have an important role to play in boosting circularity and improving other environmental outcomes. Landfilling remains a persistent social and environmental challenge, with uncontrolled disposal—representing 57% of global waste treatment (see Figure six)—causing uncontained negative impacts, such as pollution from leachate and harmful gases, health hazards and land degradation. These landfills also incur financial costs that often impact local communities. While controlled landfills are better than uncontrolled dumpsites, they are still not ideal: they cause environmental, social and health impacts and potentially lock away valuable resources, making them unavailable for cycling.[93] A shift towards higher-value waste management will be crucial in reducing this indicator's share, which can be driven by suitable infrastructure and legislation, including landfill diversion targets, taxes and bans—all of which have had success at reducing landfilling rates in the EU.[94] However, their success hinges on the availability of fit-for-purpose waste processing infrastructure and technology for plastics, textiles and organic waste, for example.

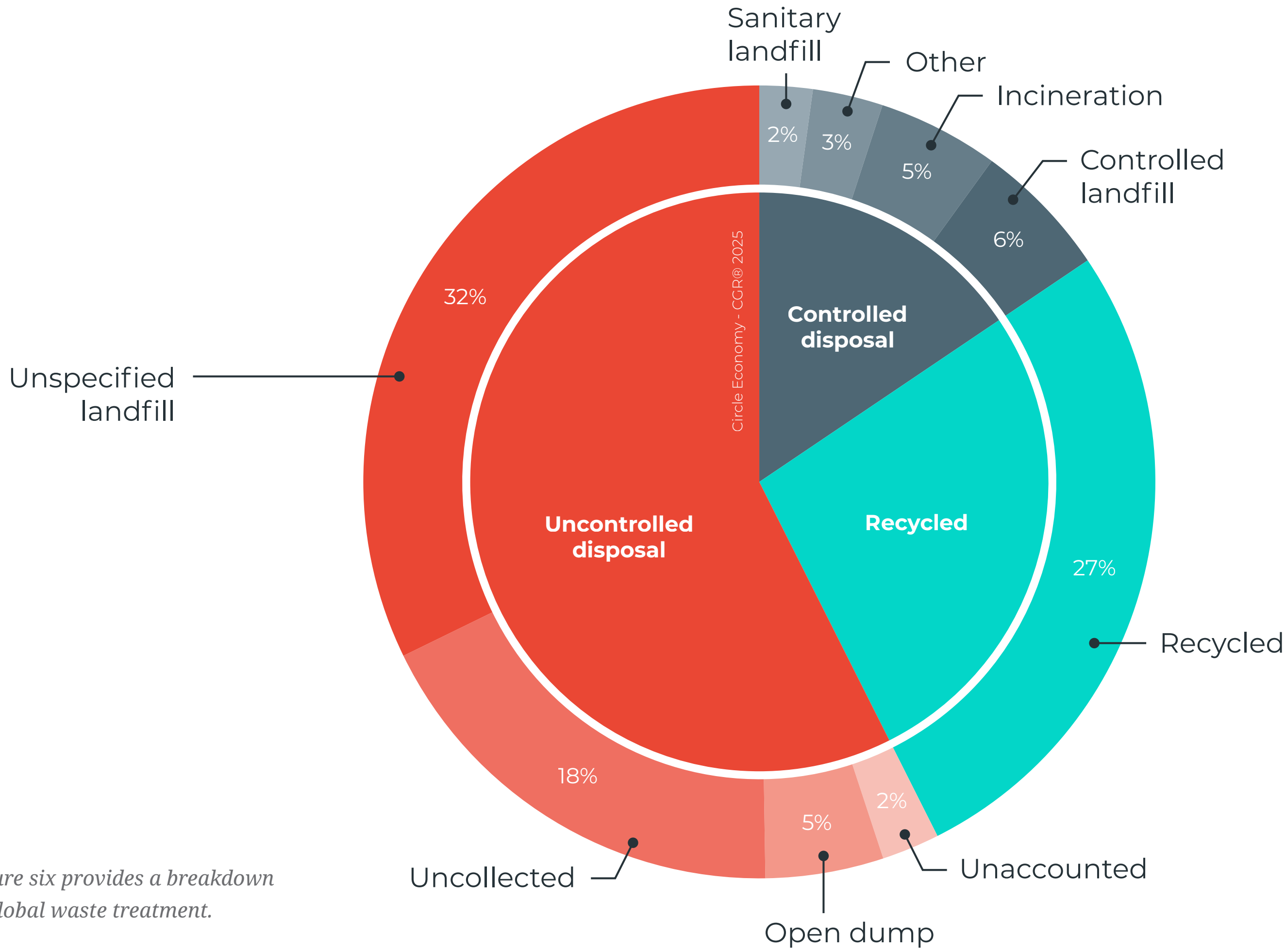
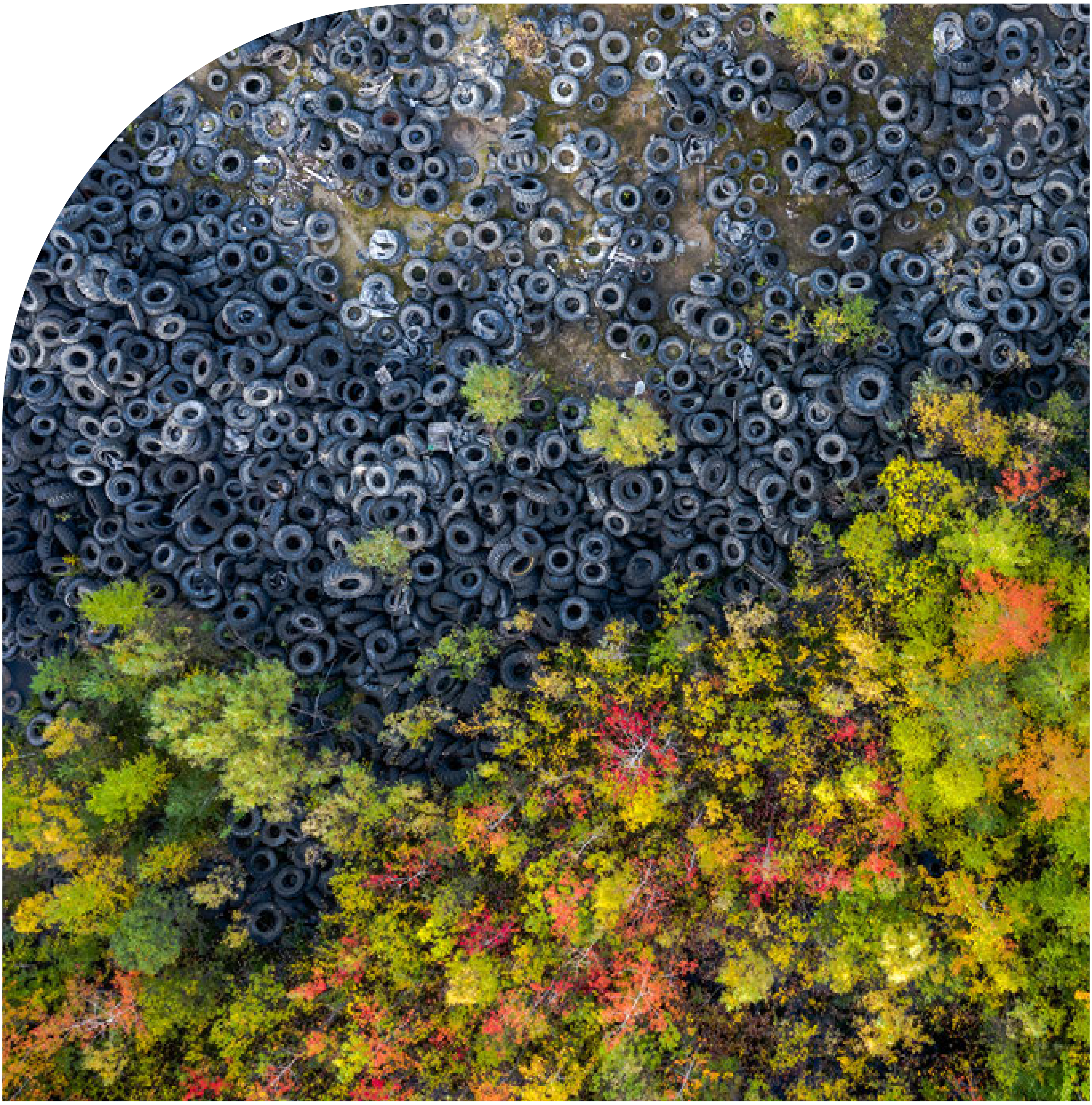


Figure six provides a breakdown of global waste treatment.

Being tied to the Circularity Metric, this indicator shares its sub-indicators: total material extraction, total waste generation, waste as a share of Processed Outputs, the global waste collection rate, the global recycling rate, and the controlled disposal rate. As material extraction decreases and global waste collection and recycling rise, the share of Virgin, Non-Renewable Materials will fall; tracking these indicators thus gives insight into the factors underpinning current rates and scales of non-renewable inputs.



2.2.3 Fossil Fuels

This indicator represents fossil-based energy carriers—such as those derived from petroleum, oil shale and tar sands, coal, and natural gas—burnt for energy. These flows are inherently non-circular: as they are combusted, they release greenhouse gas emissions into the atmosphere. Once released, these emissions are almost impossible to recapture or reuse at the speed, scope and scale necessary to limit warming to 1.5-degrees.[95]

13.3%

of materials flowing into the economy are…

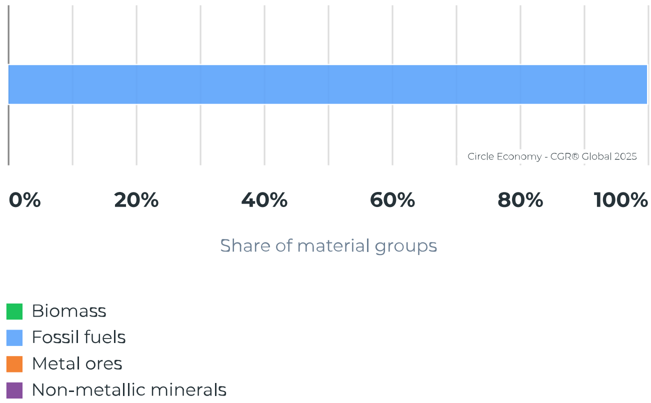
Fossil Fuels used for energy purposes.

21.6%

of materials flowing out of the economy are…

Emissions and waste from Fossil Fuels used for energy purposes.

(Input) Fossil Fuels broken down by material group



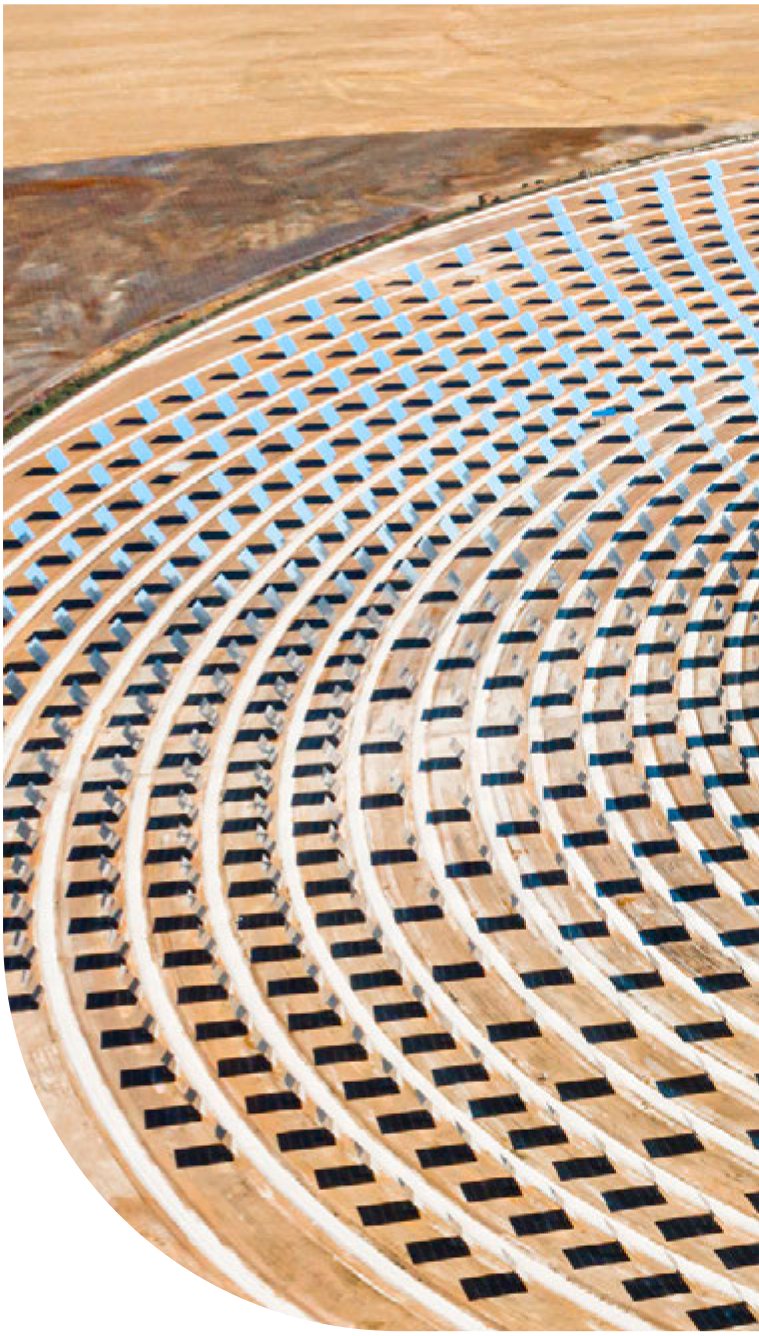
Desired outcome:

Initiate a managed transition away from fossil fuel use for energy by: 1) Prioritising improvements in systemic efficiency and 2) Transitioning to an energy system that's electrified where possible and based on renewables.

Commentary:

As a key contributor to climate change and other environmental impacts, fossil fuels are one of the most impactful material groups (see Figure seven). This mirrors global economic growth, with the two having a tight historical relationship. Fossil fuels are also the most traded natural resource, accounting for around half of traded materials globally in 2020.[96] As fossil fuels remain the dominant energy source today, the scale of fossil fuel use poses a risk to planetary health.[97] Their applications are vast: coal is used for power generation and processing materials such as metals and chemicals, oil primarily powers transport, and natural gas is used for electricity generation, heat, and as chemical feedstock. Without systematically restructuring how we power transport, generate electricity and process materials—in addition to scaling down these activities—fossil fuel demand is set to grow.

Rising global energy demand is driving fossil fuel dependence—but the circular economy transition can support a sustainable, responsible energy transition. Global economic growth and energy demand have historically been closely coupled, with energy demand increasing by 1 to 2% per year. This growth can partially be attributed to population growth, but it is also driven by a rise in average energy use per capita. For example, global average energy use per person increased from 1.55–1.65 tonnes of oil equivalent in 2000 to 1.78–1.80 tonnes in 2021.[98] Without making systemic improvements in efficiency, total energy consumption will continue to grow—making the shift from fossil fuels to a low-carbon energy system even more difficult, as new renewable energy will have to both replace existing fossil fuel capacity and meet additional energy needs. At the same time, the circular economy itself will require significant energy inputs, from reverse logistics to recycling and material recovery technologies. This underscores the importance of minimising energy demand and bolstering systemic efficiency while ensuring that energy is generated through clean, renewable sources.



Circular economy principles should be at the foundation of the energy transition to achieve sustainable resource management. The energy transition is a physical transformation and is, therefore, material-intensive. Building a low-carbon economy will require a cumulative scale-up of material extraction, particularly metals.[99] The energy transition will result in a surge in demand for critical raw materials like lithium, cobalt, and rare earth elements—resources concentrated in a few countries, creating new dependencies and supply risks.[100] A circular economy approach is crucial to reducing reliance on sensitive supply chains, enhancing resource security, and building resilience against price volatility and supply shortages—supporting a more sustainable and responsible energy transition.[101]

Decarbonisation is part of a more global circular economy: resource-light and low-carbon economies go hand in hand. The current fossil-based energy system is inherently material-intensive and linear, requiring a constant flow of carbon-intensive fossil fuels to sustain it. At the same time, developing renewable energy systems will also be initially material-intensive, especially metals and critical minerals. Many of these materials have high supply risks and environmental and social costs. Circular economy strategies can help scale renewable energy sustainably by reducing its environmental footprint—minimising both the resource extraction required and other environmental impacts of cutting carbon emissions.[102] A circular economy approach that maximises systemic efficiency in the energy system and follows circular design principles at the product, asset and system levels is essential to reduce both fossil fuel reliance and minimise the raw material footprint of the energy transition.[103]

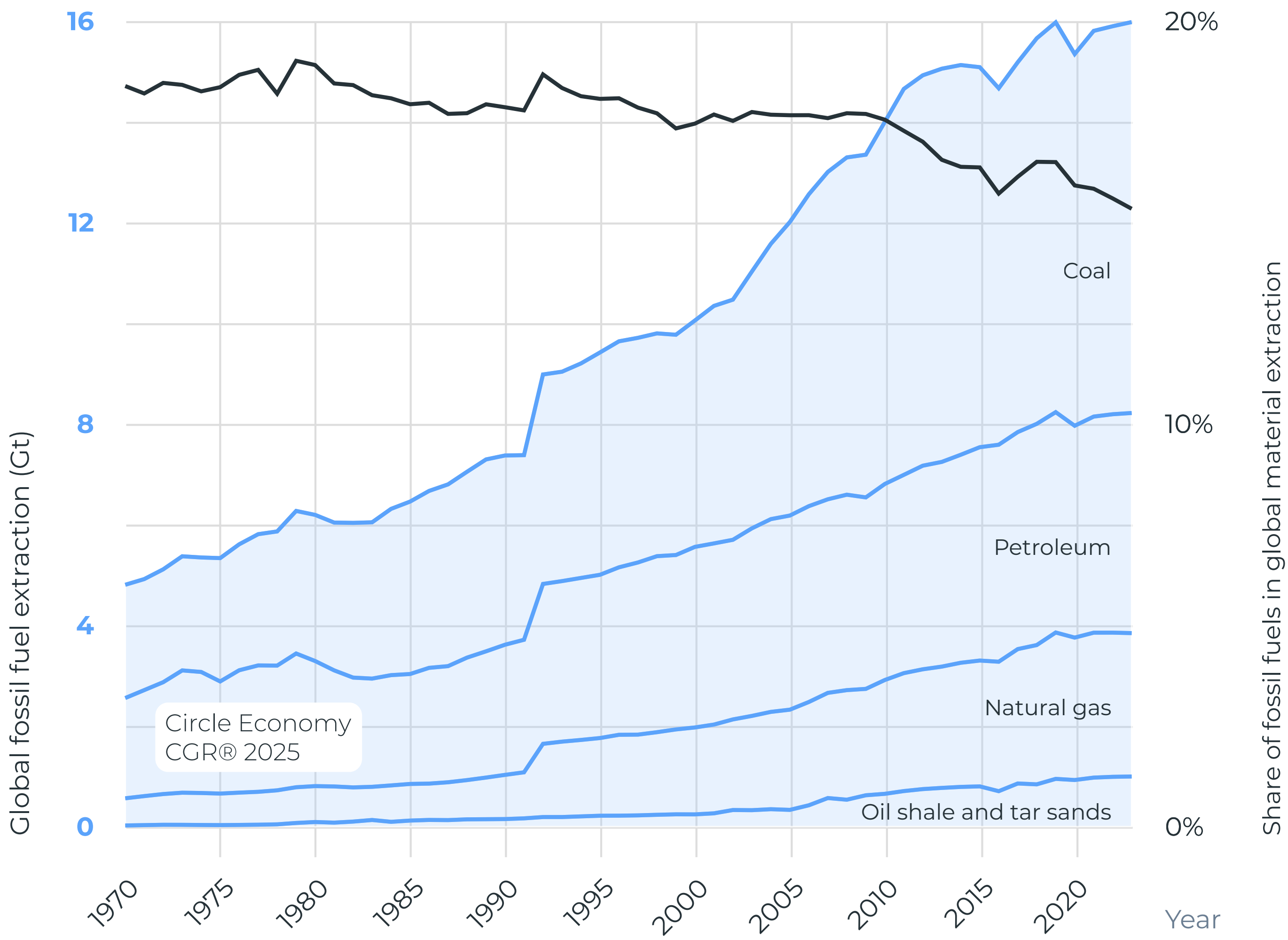


Figure seven illustrates the evolution of global fossil fuel extraction and its share of total material extraction between 1970 and 2021.

Realigning financial incentives to support circular and low-carbon solutions is important for reducing global fossil fuel demand and accelerating the transition to sustainable energy systems. High subsidies and other financial incentives can reinforce global dependence and slow the shift to circular, low-carbon alternatives. Redirection of financial flows will be needed to help the scaling down of fossil fuels. In 2021, explicit subsidies—such as the direct transfer of government funds, price support, and other forgone tax revenue—represented an estimated US$1.4 trillion (about 0.94% of global GDP).[104] Reorienting financial flows from subsidies towards decarbonisation—through a systemically efficient energy system based on electrification and powered by abundant renewables—will be necessary to reduce fossil fuel demand, mitigate environmental impacts and optimise long-term resource use.

Ultimately, the global economy should aim to reduce the rate of fossil fuel consumption while also minimising the scale of these materials used. To understand and measure progress towards reducing fossil fuel usage, it's important to break down the factors influencing these indicators through a number of sub-indicators. These indicators' status—and whether or not they have relevant global or sub-global targets—are summarised in Table five.

Input: On the input side, a number of sub-indicators give insight into the structural factors that currently contribute to the global material footprint of fossil fuel-based energy carriers. We know that transitioning to a decarbonised energy system is key to reducing fossil fuel dependence and mitigating climate change. This process has a few key components, measured by three indicators. Ultimately, we need to:

1) Optimise the energy system to help reduce **total primary energy supply,** which stands at about 579–597 exajoules[105] (or 13.8–14.3 billion tonnes of oil equivalent), with 82% coming from fossil fuels in 2021. Improving systemic efficiency in energy-intensive sectors, such as mobility, manufacturing and heating, will reduce both end-use energy demand and material use. Within the current system, improving systemic efficiency can be incredibly effective: analysis shows that global energy demand in 2050 could be up to 40% lower than today if all possible efficiencies are implemented.[106]

Indicator	Value in (year)	Trend	Global Target	Status	Sub-Global Targets (Y/N)
Total primary energy supply (exajoules)	579[111]–597[112] exajoules (2021) 570[113]–581[114] exajoules (2018)	↑	**464.5 exajoules (2030), 553.2 exajoules (2050)[115]**	Off-track	Yes
Share of final energy consumption from renewable sources (%)[116]	18.7% (2021) 17.3% (2018)	↑	**50–60%[117]**	Off-track	Yes
Share of electricity in total global energy consumption (%)[118, 119]	20.1% (2021) 19.5% (2018)	↑	None	n.a.	Yes
Global anthropogenic greenhouse gas emissions (excluding emissions from LULUCF) (tonnes of CO_2e)[120]	53.0 billion tonnes (2021) 52.4 billion tonnes (2018)	↑	**28.4 billion tonnes[121]**	Off-track	Yes
Emissions as a share of Processed Outputs (%)[122]	54.8% (2021) 55.4% (2018)	↓	None	n.a.	No

Table five lists each sub-indicator, elaborating on how these figures have changed over a five-year period and whether we are on track to meet global targets (if any).

2) Prioritise electrification from renewable energy to increase the **share of electricity in total final energy consumption** (which was 20.1% in 2021, up from 19.5% in 2018). Because electricity (from renewable energy technologies) requires less primary energy supply to generate, electrifying as many activities as possible—from transportation (think small electric vehicles) to building heating (through heat pumps, for example) and steel production (through green hydrogen)—will be crucial for decreasing fossil fuel dependence.[107] Electrification is increasing, but at a slower rate than overall energy demand, while the carbon intensity of electricity generation keeps growing, not decreasing.[108]

3) Systemically optimise and scale up decarbonised electrification across industries to rapidly increase the **share of total final energy consumption from renewable sources** (18.7% in 2021, up from 17.3% in 2018).[109] This is important because, so far, new renewable energy has overall *supplemented* not *replaced* existing fossil-based energy capacity.

Output: On the output side, indicators capture the environmental impact of fossil fuel consumption, giving insight into the consequences of using these materials. **Global anthropogenic greenhouse gas emissions** (excluding emissions from LULUCF) totalled 53 billion tonnes of CO_2e in 2021, with fossil fuel combustion as the primary driver: 72% of this stems from energy use. This underscores the urgent need to transition away from fossil fuels to curb climate change. Measuring **emissions as a share of Processed Outputs**—the materials that leave an economy as either emissions or physical waste—gives insight into fossil fuel dependence, with a high share indicating that an economy depends heavily on emissions-intensive activities. Of the total output produced by the global economy, over half (54.8%)[110] is emissions. Unlike solid waste, which can often be recovered and recycled, capturing emissions for reuse is not yet feasible at scale. This limits the pool of waste available for circular recovery, reducing opportunities for reuse and recycling. This indicator varies by region: industrialised regions like North America (65%), Europe (61%) and Asia & Oceania (53%) have higher shares, while Latin America (32%) and Africa (21%) have significantly lower shares.

2.3 Stock build-up

This category includes a single indicator that measures the share of virgin material flows being added to global stocks—such as buildings, infrastructure, machinery, and vehicles—in net terms. Stock build-up refers to the input and accumulation of materials within an economy over time—crucial for understanding the long-term dynamics of material use and its implications for sustainability and resource management. These additions to stocks are not inherently good or bad. They can be necessary to meet societal needs like housing and transportation. However, they are also significant drivers of material use, contributing to the high level of resource consumption that limits circularity. While materials captured by this indicator may have circular 'potential', considering the time element is also important here. These materials are locked into long-lived assets and unavailable as secondary material inputs for many years or even decades, and this delay creates a temporal gap or 'lag' in circularity. For this reason, strategies that optimise stock build-up, extend the lifetimes of existing assets, and enhance future material recovery are crucial for improving circular flows over time.

While this indicator captures net stock additions—the difference between inflows and outflows—this dynamic is also influenced by reuse, remanufacturing, or repurposing taking place 'within' stocks. Many products are recirculated but not recycled: they aren't classified as Secondary Materials and captured by the Circularity Metric. Examples include second-hand electronics and furniture reused on a smaller scale or asphalt or vehicles on a larger scale. While this indicator does not capture the scale at which reuse and other R-strategies take place, we can broadly assume that these strategies will lessen demand for new stock build-up,[123] thus optimising Net Additions to Stock.

** While a large portion of secondary materials is used in long-lived applications and contributes to Gross Additions to Stocks, the net accumulation shown by the Net Additions to Stock indicator does not include secondary materials. In a static EW-MFA accounting framework, the amount of secondary materials entering (in Gross Additions to Stock) and recyclable waste leaving (in the Demolition and Discard flow) from Accumulated Stocks will always be the same. In this framework, all secondary materials and recyclable waste—whether used in long-lived or short-lived applications—are recorded by the inflows and outflows of Secondary Materials.*

2.3.1 Net Additions to Stock

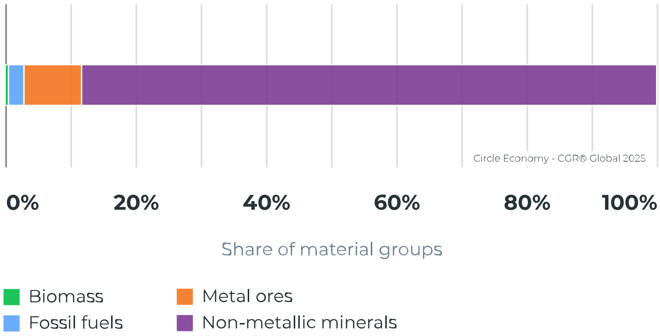
Net Additions to Stock measures the rate of physical growth in an economy's material accumulation. This indicator represents the difference between the virgin materials* added to the accumulated physical stock and those removed over a given period of time, usually upwards of one year. Unlike material flows—which track how materials *move* through the economy—stocks represent materials that *accumulate* in the economy. As economies develop, material flows contribute to material stocks—a relationship that shapes future resource demand for maintenance and replacement and influences future waste generation and management. Both flows and stocks should be examined to understand how materials are extracted, processed, accumulated and ultimately either lost or cycled.

38.0%

of materials flowing into the economy are...

Net additions of virgin materials—largely non-metallic minerals and metals, but also small amounts of fossil fuels used for material purposes and technical biomass—accumulated in stocks.

Net Additions to Stock broken down by material group



Desired outcome:

Optimise material accumulation in stocks by: 1) Maximising the use and adaptation of existing physical assets, such as buildings, infrastructure, and machinery, instead of building/producing new, 2) Increasing the share of sustainably-managed renewable materials in stock composition, and 3) Prioritising circular design principles—such as design for durability, repairability, disassembly and recyclability—in new stock additions.

The combination of rapid urbanisation and economic growth is driving the increasing accumulation of stock worldwide.[125] The amount of built-up land is a key driver of per capita material demand, as expanding infrastructure and urban areas require substantial resource inputs.[126] Urbanisation is accelerating, with the share of people living in cities growing from 47% in 2000 to 56% in 2021.[127] Projections suggest this could reach 68% by 2050,[128] adding 2.5 billion more people to urban areas. Significant stock additions in cities will be necessary to accommodate this growth and to provide decent living conditions for the one-third of urban residents who currently live in slums and informal settlements, often without access to basic services. Going forward, it will be crucial to balance the provision of essential services with optimised material use and the integration of circular principles.

Commentary:

Stock build-up plays a crucial role in shaping global material flows, waste generation, and emissions, acting as both a driver of and a constraint on circularity. Net Additions to Stock represent a significant portion of global material use, with approximately 38% of materials entering the economy remaining in use for an extended period. However, this indicator doesn't capture the materials required to operate Accumulated Stocks. When those are included, this figure increases to more than 70%, highlighting just how many materials are used to construct, maintain and operate them. The rate of stock growth—recorded by Net Additions to Stock—has grown spectacularly, causing Accumulated Stocks to increase 23-fold over the 20th century and to roughly double every two decades.[124] The scale and pace of this build-up have profound implications for resource efficiency, emissions, and waste management. While growing material stocks contribute to economic development and improved living standards, they may also increase long-term resource dependency and pose challenges for future material circularity. This is because poorly designed stock—an energy-inefficient building that requires natural gas to heat, for example—increases the long-term material requirement related to it. On the other hand, long-lived assets designed with circular principles—a modular, timber-based, energy-efficient building with solar panels and a heat pump, for example—can reduce long-term material dependency.

Embedding circular economy principles into urban planning and development will be key to reducing global resource use and achieving a more circular economy. As urban areas grow, so too does stock build-up, thus locking in materials for decades, shaping material demand patterns and slowing the rate at which these resources can re-enter the system through reuse or recycling. Without strategies to optimise urban planning and stock build-up—such as localised operations, material-efficient construction, adaptive reuse, and designing for longevity—cities risk becoming long-term hotspots of growing material demand, exacerbating resource depletion and environmental pressures. By 2050, urban material consumption is projected to grow by 150%, from 40 billion tonnes in 2010 to 90 billion tonnes.[129] However, designing compact, resource-efficient cities based on circular economy principles could cut greenhouse gas emissions by 36–56% while also lowering demand for metals, land, energy and water.[130] At the same time, actively 'mining' materials from Accumulated Stocks—instead of the natural environment—provides another key opportunity to boost circularity by increasing the pool of secondary materials available.

The sheer scale of non-metallic mineral use—driven by stock build-up—has fuelled the unprecedented accumulation of human-made materials. While all material groups are linked to stock build-up, non-metallic minerals make up the largest portion. This is in part due to their substantial weight: the sand and limestone used to produce cement and gravel used to build roads and fill construction sites, for example. Non-metallic mineral extraction has grown exponentially in past decades, from 8.5 billion tonnes in 1970 to 47.9 billion tonnes in 2021 (see Figure one). This is a key reason why, in 2020, humanity reached a new milestone when the mass of human-made things surpassed that of all living things on Earth—plants, animals and humans.[131] The weight of Accumulated Stocks on Earth has also significantly increased over the past decades, estimated at over 1 trillion tonnes in 2016. The majority of these materials are found in roads (313 billion tonnes), residential buildings (290 billion tonnes), civil engineering (243 billion tonnes) and non-residential buildings (234 billion tonnes). Machinery and other shorter-lived products contribute far less, with the weight of motor vehicles totalling just 3 billion tonnes, for example.[132] Projections indicate continued stock expansion: for example, residential building stock is projected to grow by 50% by 2050, while the global service-related building stock is projected to increase by 150%.[133]

While stock build-up has become a key driver of global resource use, a single global indicator overlooks significant differences between regions and countries. Upper-middle and especially high-income countries have historically built up their stock,[134] while lower-income countries are still developing stock to meet their residents' societal needs. Total floor space is expected to grow by 97 billion square metres between 2022 and 2030, with the bulk of this notable increase likely to be driven by lower- and middle-income countries.[135] This underscores the need for sustainable practices in construction and resource management to mitigate the environmental impacts associated with this growth: Lower-income countries should develop stock in line with circular principles that maximise resource efficiency—such as prioritising secondary and low-carbon materials and designing for durability, reuse and disassembly at end-of-life—and sustainably optimise and manage stock expansion.[136] At the same time, the current weight of per capita stocks is higher in industrialised countries than in developing countries:[137] residents of high-income nations consume significantly more materials than those in low-income nations, regardless of urbanisation levels. For this reason, higher-income, stock-rich countries should aim to minimise new stock growth, prioritise renovation and adaptation over building new, maximise the intensity of building use, and maximise material efficiency for long-lasting manufactured goods, for example. Durable, repairable, and modular design approaches can significantly extend the usability of these assets.

Setting a specific goal for the share of Net Additions to Stock is complicated, as this will vary significantly by context. For example, a country's target for a given year would depend on historic stock build-up, how current Accumulated Stock is being managed, and how needs for new stock additions are being met. It's more important that the materials captured by this indicator are sustainably optimised so that the full potential for circularity can be met. Stock build-up is measured using input-side sub-indicators, as inputs inherently account for both outputs and net accumulation. However, stock dynamics introduce a significant time lag because materials entering the system today do not immediately translate into outputs. Many of these materials become part of long-lived assets—such as buildings, infrastructure, and vehicles—remaining in use for years or decades. Over time, these materials gradually exit the economy, shaping output-side indicators. This means that current outputs are largely influenced by past inflows rather than present material use. Resources that leave the system as outputs are classified under different indicators: either waste destined for recycling or waste disposed of without recovery (see Figure three).

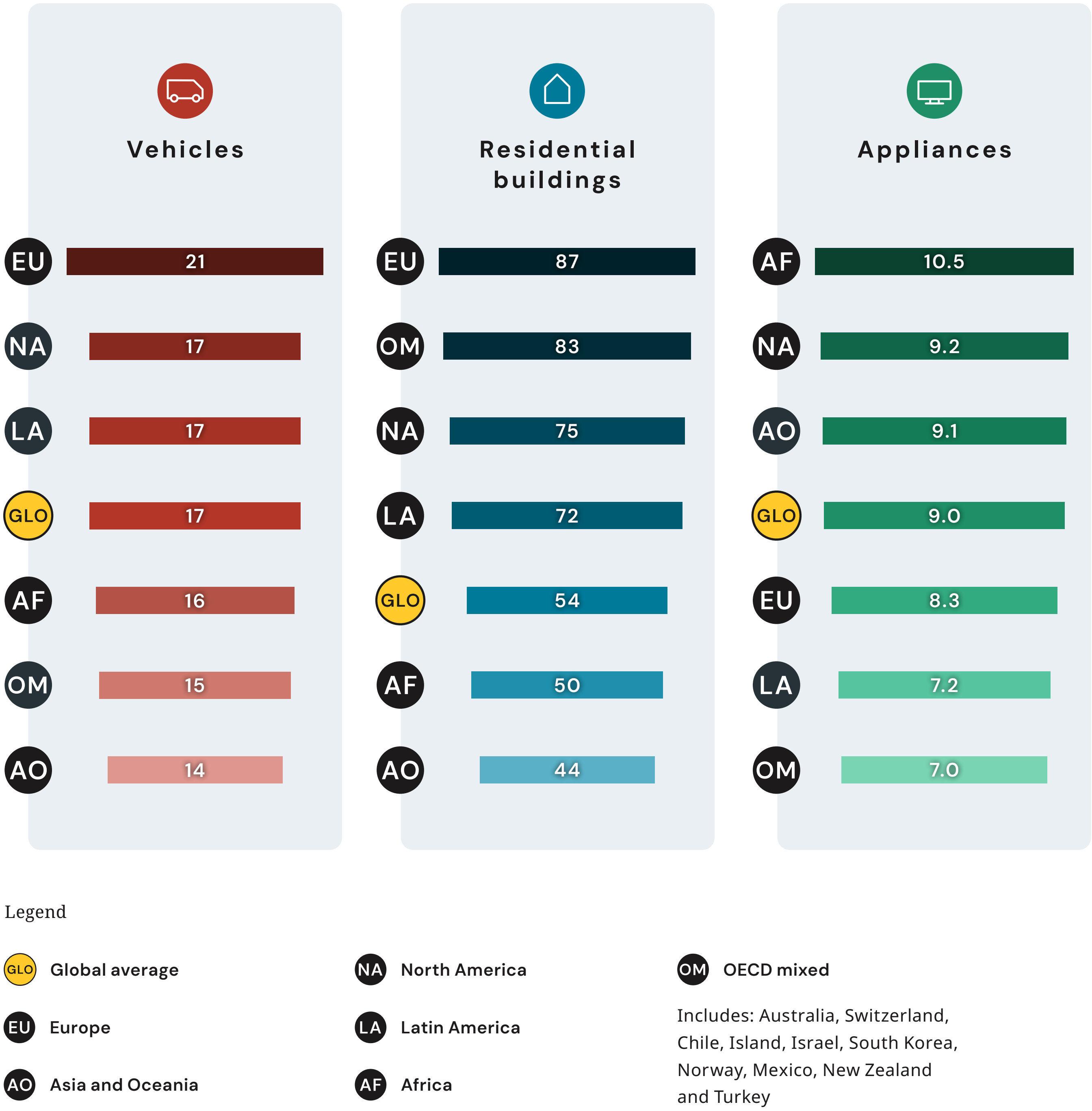
These indicators' status—and whether or not they have relevant global or sub-global targets—is summarised in Table six.

Input: Input-side sub-indicators for Net Additions to Stock give insight into the flows of materials included in societies' physical stocks, as well as their longevity. The **global growth rate in built-up areas**—an increase of 33% between 2000 and 2022—reveals the rising material demand for new buildings, infrastructure, and transport systems.[138] This is particularly noticeable in rapidly developing regions where built-up areas in Asia or Africa have grown 40% over the past two decades, compared to 20% for Europe and North America. Measuring the **share of renewable biomass out of Net Additions to Stock** (0.4%) helps track progress towards a bioeconomy. Most of this progress, at least from a mass perspective, will relate to changes in the composition of stocks as opposed to other (still important) applications such as biorefinery products. However, to achieve this, we need to respect the principles of a circular bioeconomy, as explored on page 34: minimising carbon emissions and cycling nutrients back into the ecosystem at the right place and rate.

Additionally, optimising the **average lifetimes of asset categories**—such as residential buildings, vehicles, and appliances (see Figure eight)—provides insight into their durability and replacement cycles. This directly influences the rate at which new materials are needed. By slowing material turnover, we can minimise resource demand in the long term.

Global stock optimisation

Lifetime of selected assets compared to the global average



This visual is built using data from different sources and with different reference years ranging between 2007 and 2015.

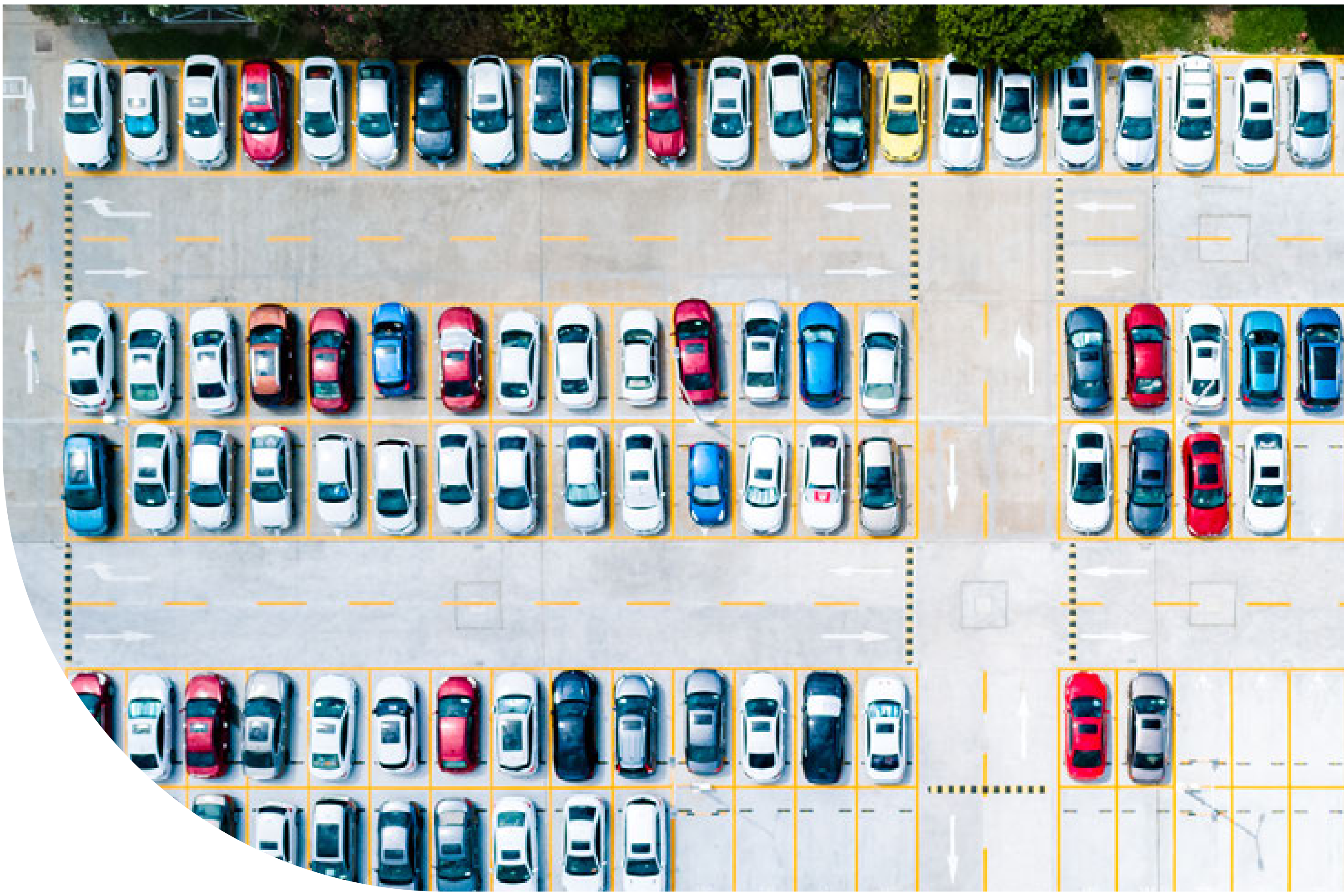
Unit: years

Figure eight illustrates the lifetimes of three asset categories across world regions.

Indicator	Value in (year)	Trend	Global Target	Status	Sub-Global Targets (Y/N)
Growth rate in global built-up area (%)[139]	+ 33% (2000–2020)	↑	None	n.a.	No
Renewable biomass as a share of Net Additions to Stock[140]	0.4% (2021) 0.6% (2018)	↓	None	n.a.	No
Average lifetime of residential buildings (years)[141]	54 years (various years)*	n.a.	None	n.a.	No
Average lifetime of vehicles (years)[142]	17 years (various years)*	n.a.	None	n.a.	No
Average lifetime of appliances (years)[143]	9 years (various years)*	n.a.	None	n.a.	No

Table six lists each sub-indicator, elaborating on how these figures have changed over a five-year period and whether we are on track to meet global targets (if any).

** Based on the latest available data from each country or group of countries.*



A circularity indicator set fit for the future

Now that you know the breakdown of the various parts of the Circularity Indicator Set, you may wonder: what is a ‘better’ allocation of material inputs? The Circularity Metric is too low, and our use of Non-Carbon-Neutral Biomass, Virgin, Non-Renewable Materials, and Fossil Fuels is too high, but estimating appropriate rates for some indicators—such as Carbon-Neutral Biomass and Net Additions to Stock—is complex. Table seven demonstrates the results of a thought experiment using key global targets to reimagine the distribution of the Circularity Indicator Set in a more sustainable and circular world. It’s assumed that:

- The Circularity Metric increases to 17% by 2032;[144]
- Virgin material use is capped at the estimated sustainable level of 8 tonnes per capita[145]—close to the level of consumption in 1970—for a projected population for 2032;[146]
- Emissions are reduced by 25 billion tonnes of CO_2e by 2030, to stay below 1.5-degrees of warming;[147]
- Biomass consumption is reduced by 75% by 2050 (compared to 2020 levels),[148] compatible with a cap on bio-based material consumption at 2 tonnes per capita.[149]

Crucially, the absolute volume of material throughput must decrease. As shown in Table seven below, applying these targets results in a significant reduction in the scales of each indicator. This highlights the importance of considering overall **scales**, at the very least, in conjunction with—if not instead of—rates. In this scenario, for example, the rate of Carbon-Neutral Biomass—a potentially ‘circular’ indicator—falls simply because less materials are being used overall.

	2021		2032	
	Rate (%)	Scale (billion tonnes)	Rate (%)	Scale (billion tonnes)
Secondary Materials/Circularity Metric (Input Technical Cycling)	6.9%	7.3	17.0%	14.3
Carbon-Neutral Biomass (Input Ecological Cycling Potential)	21.5%	22.8	20.4%	17.1
Non-Carbon-Neutral Biomass (Input Non-Renewable Biomass)	2.2%	2.3	0.0%	0.0
Other Virgin, Non-Renewable Materials (Input Non-Renewable Flows)	18.0%	19.2	14.4%	12.1
Fossil Fuels used for energy purposes (Input Non-Circular Flows)	13.3%	14.1	6.9%	5.8
Net Additions to Stock	38.0%	40.3	41.2%	34.6
Total	100%	106.1	100%	83.9

Table seven presents the results of a thought experiment, illustrating how achieving various global sustainability targets could impact the distribution of the Circularity Indicator Set and, more crucially, the scale of material throughput.

Circular economy metrics for businesses

While governments define regulatory frameworks within their jurisdictions, businesses—by operating global value chains—directly shape the actual performance of global resource flows. This is why a growing number of businesses are measuring and reporting on the circular economy performance of their own operations and value chains. A growing number of measurement frameworks and reporting standards[150] are making it easier for businesses to report on such matters using language and indicators that are well-understood and defined. While the indicators explored throughout this chapter are macro-level and perhaps better suited to national or regional governments, the importance of businesses in driving the circular transition should also be recognised.

Measuring the circularity of global resource flows requires a very different set of indicators than measuring the circular economy performance of individual actors—like businesses—that are engaged with those resource flows. Businesses can set out to measure the performance of individual products, businesses, value chains, or entire sectors, each time setting different system boundaries for their assessments. This makes it very important for organisations to clearly communicate which scope they have applied to their analysis when reporting on circular economy performance, much like the use of Scope *1, 2 or 3* in communications on greenhouse gas emissions. More guidance on proper scope setting in the field of circular economy performance measurement can be found in our white paper on this topic: *Circular Economy Boundary Framework: Setting circularity scopes for impact and material measurements*.

3 The way forward

Calls to action for stakeholders in government and business

Based on years of research, we know the potential of the circular economy to meet the needs of people around the globe while bringing material use back within the safe limits of our planet—helping to decouple wellbeing from resource consumption and environmental impacts. We also now know that we're not yet leveraging this potential: much remains to be harnessed. The previous chapter of this report outlined the 'what', highlighting trends of concern, pinpointing where we're not on track and quantifying baselines from which to measure and monitor progress. It showed how various headline indicators relate to and interact with each other, acting as levers to boost the Circularity Metric. By minimising 'linear' inputs, optimising stock build-up, and ensuring the circularity of biomass, we could be well on our way to a more circular world. Now that we know what needs to be done, this chapter synthesises our key findings into five crucial and interconnected goals to rally behind and explores the 'how'. It highlights the actions key stakeholders across government and industry should take to create the right environment for a global circular economy to flourish and implement real circular solutions on the ground.

The rate of secondary material use is steadily decreasing, and the vast majority of materials entering the economy are virgin. We need to reduce global resource demand and scale down material throughput with sufficiency strategies that avoid demand for materials, energy, land and water while providing for people's wellbeing within planetary boundaries.

Although the scale of secondary material use is slowly increasing, the rate is falling, outpaced by overall growth in virgin material use. In 2021, we reached a historical milestone, reaching 100 billion tonnes of material extraction in one year. This is more than a three-times increase from 1970, with average growth of 2.3% per year.

Why is this critical? Growing global resource use is the main driver of the triple planetary crisis of climate change, biodiversity loss and pollution.[151] At the same time, concerns related to resource depletion and long-term resilience enable governments and businesses to explore ways to make economies less material intensive.

We should boost secondary material use and reduce extraction in tandem, and help ensure governments and businesses embrace principles of resource efficiency and sufficiency. This means promoting circular design principles, optimising the lifetime of existing products and components, and ensuring recycled material inputs become the norm for businesses in many industries and regions.

We're consuming more and more biomass at the expense of the safety and stability of the natural world, driving climate change and biodiversity collapse. Biomass extraction and use aren't sustainable by default: they need to meet strict sustainability criteria to safeguard ecosystems.

Ecological cycling, a cornerstone of the circular economy, is a major blindspot that requires more critical attention. Although it's widely accepted that renewable resources play a starring role in a circular economy, it's crucial not to assume that using more renewable resources is sustainable by default. Biomass extraction has more than doubled in the last 50 years, and poor practices like heavy fertiliser use, inefficient land allocation and use, and food waste generation are commonplace.

Why is this critical? Biomass extraction drives a range of environmental impacts worldwide: it represents nearly one-fifth of global emissions and accounts for over 90% of land-related biodiversity loss.[152] All nations and industries inherently depend on biomass and the ecosystem services it sustains—from clean air and water to soil fertility and climate regulation. A functioning natural ecosystem is fundamental to economic stability and human well-being.

We should make biomass use (and ultimately, land use management) truly sustainable by ensuring extraction allows for sustainable regeneration, prevents waste and pollution, and supports biodiversity. Nutrients need to be cycled back into the ecosystem in the right place and at the right rate, and carbon emissions should be minimised.

Rapid stock build-up is a key driver of growing resource use. Optimising material stock build-up will be key to achieving long-term resource efficiency and sufficiency while reducing excessive material accumulation.

Almost two-fifths of materials consumed by the global economy each year feed into stock build-up—net materials accumulated in new buildings, infrastructure and machinery that stay in use for many years. This rate has grown spectacularly, with stocks increasing 23-fold over the 20th century. Stock build-up is not inherently 'bad'; on the contrary, many countries need to invest to ensure that the local populations have access to basic services, and we need to build up infrastructure globally to support renewable energy generation, distribution and storage capacity. However, stocks should be built up and managed with care to ensure optimal resource use.

Why is this critical? Stock build-up is a key determinant of past, present and future material flows. To reduce waste, emissions, and overconsumption, preventing the excess accumulation of materials in stock is essential. What's more, materials available for stock build-up are finite: as increasingly-rare metal inputs become locked up in long-lived assets, for example, nations and industries will not be able to maintain current infrastructure levels without adopting circular approaches to resource management.

We should flatten the spike in global material use by minimising unnecessary stock growth in high-income economies—prioritising renovation and adaptation over building new, for example. At the same time, we need to sustainably optimise and manage stock expansion through compact, urban development and circular design principles in lower-income countries. Increasing high-value resource recovery from construction and demolition waste and recovering critical metals from infrastructure and equipment will also be crucial.

To transition away from fossil fuel consumption, we must accelerate electrification and scale up the deployment of well-designed, renewable energy systems to sustainably meet growing energy needs.

From a raw materials perspective, the share of fossil fuels relative to total material extraction has shrunk over the past fifty years—but absolute fossil fuel use is still increasing. While there's been some progress in terms of electrification and renewable energy deployment, this is not occurring at the speed and scope necessary to reach global targets. To progress towards an electrified world powered by renewables, we need to undertake the physical transformation needed to decarbonise economies, following circular principles.

Why is this critical? Fossil fuel use is the largest contributor of global greenhouse gas emissions, responsible for 78%.

We should reduce the rate and scale of fossil fuel consumption—transitioning existing fossil-based energy capacity to renewable technologies designed for longevity, reuse and recycling, reducing the need for ongoing material use in the long-term.

The overall scale of virgin, non-renewable materials destined for landfill is growing. We need to minimise wasteful processes across key resource-intensive supply chains by prioritising circular design, sufficiency and efficient resource use, and better manage unavoidable waste.

More than one-fifth of global material use is represented by materials that could be cycled but currently are not. This indicator has grown by more than one billion tonnes between 2018 and 2021. Consumption and extraction are growing rapidly, greatly outpacing improvements in resource recovery technologies and waste management capacity. While collection rates are improving, value recovery remains far too low. Secondary raw materials still face price competition from cheaper virgin materials, so advancements in recycling technologies and environmental regulations are needed to shift the market.

Why is this critical? A large portion of the waste produced by the global economy isn't properly handled, and materials mismanaged along the supply chain represent a huge lost opportunity for value recovery. At the same time, landfilling and uncontrolled disposal remain a pervasive social and environmental challenge linked to a range of impacts, from pollution to health hazards to land degradation.

We should reduce this indicator to as close to 0% as possible. Circular design principles can prevent the generation of difficult-to-manage wastes. Infrastructure should be developed to increase high-value applications for waste, and waste management infrastructure should be improved and backed by regulation.

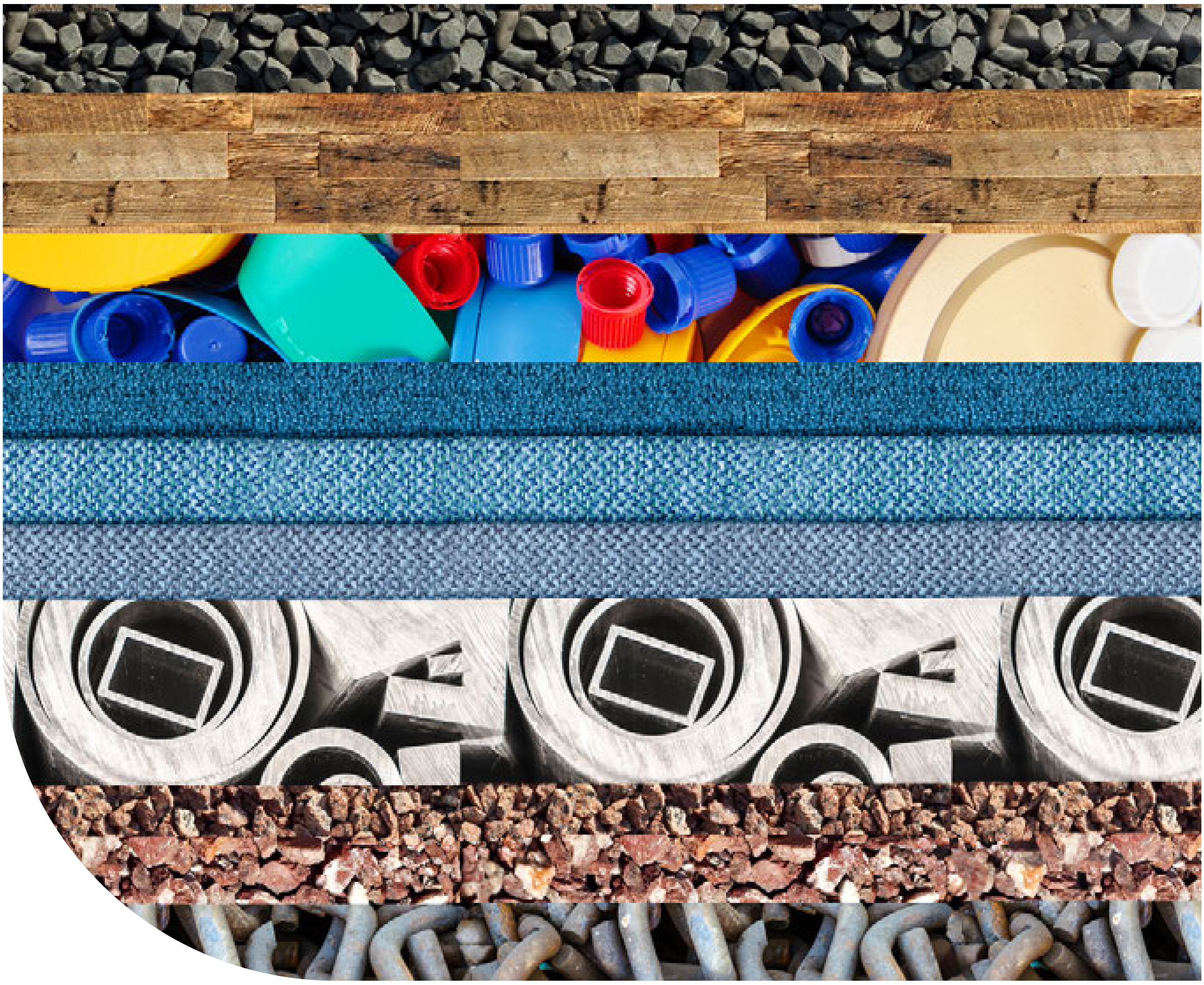
What *governments* can do

Take the lead in enabling circular resource use: system-level transformation requires governments to set a clear vision and drive the much-needed economic upgrade. This means driving a strategic approach to resource policy, ensuring decisive actions follow intentions. It goes without saying: the shift to a circular economy cannot happen without the right policy environment and government action that phases out wasteful practices and promotes and supports smarter ways of meeting people's needs. Political leadership is crucial to set priorities, drive investment, and build public support for change. Governments may have a bigger role to play than correcting market failures: they should actively shape economies to reduce dependence on virgin materials, cut waste and emissions, and create viable new opportunities for businesses and workers. They rally behind and unify circular initiatives and set the objectives necessary to address urgent socioeconomic challenges in a rapid, socially just way. In parallel, there is room to embed circular economy thinking and interventions into existing climate policy efforts by building circularity into Nationally Determined Contributions, for example.[153]

Shape the right economic conditions for circularity to flourish. Governments have the potential to reshape economic incentives in line with circular economy principles, ensuring that they become the default rather than the exception. Market designs and pricing mechanisms need to be aligned with circular economy goals: rethinking fiscal policies and regulating finance so that flows of capital are redirected to sustainable resource use and away from linear, resource-depleting, polluting activities. A smart policy mix can level the playing field and encourage businesses to transform their operations. Governments can also strengthen extended producer responsibility (EPR) and eco-design regulations to not only promote smarter waste management but drive circular design by encouraging circularity upstream, ensuring products are designed for durability, repairability and recyclability from the outset.[154] These measures both drive sustainability and help build more resilient economies by reducing dependence on finite resources, mitigating supply chain risks, and fostering long-term economic stability.

Actively support and participate in global governance, as no country can tackle resource use reduction in a vacuum. In our highly globalised world, international collaboration is essential to effectively managing global material flows and reducing extraction. Despite increasing recognition of resource overconsumption, there is no global governance framework to help ensure sustainable resource use nor targets to work towards. An international body—akin to the Intergovernmental Panel on Climate Change or Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services—could help steer action by providing science-based assessments and policy guidance. This body would focus on shaping long-term resource management by setting global benchmarks, tracking material use, and guiding value chain transformation. This aligns with suggestions made in the negotiating text of the legally binding agreement on plastics pollution, for example.[155] This would provide countries and companies with ambitious, science-based insights to inform material use targets alongside climate and biodiversity goals. Immediate efforts towards this end goal could build upon existing work in this area, such as the International Law Association's *Guidelines for Sustainable Natural Resources Management*[156] and the International Resource Panel's *Mineral Resource Governance in the 21st century.*[157]

Establish an International Materials Agency to guide governments in measuring and monitoring sustainable resource use and circular economy progress. Robust data and transparency are essential for both monitoring the transition and creating accountability. Improved transparency, data collection, and reporting mechanisms aligned with international standards are needed to drive smarter decision-making. These systems help identify trends, evaluate the impact of policies, and refine strategies over time. They are also crucial to ensure that policy action is driving real change rather than merely shifting impacts elsewhere. Crucially, however, this agency's role would be distinct from target-setting—it would focus solely on data provision. By providing access to consolidated material flows and presenting their impacts, an International Materials Agency could provide relevant insights at the national level. In this sense, it could provide better: (1) **Orientation** through material consumption targets and related science-based guidance, including a target akin to a 'net zero for materials', (2) **Measurement** through data, indicators and metrics that capture the wellbeing performance and material efficiency of key provisioning systems such as housing, mobility, food, and energy, and (3) **Economic incentives** to realign financial flows with resource-light, low-carbon and nature-positive solutions. It could also ensure the best-practice transfer of knowledge and facilitate collaboration among practitioners across policy and business.



What *businesses* can do

Set clear, measurable goals towards a circular transition that is both environmentally responsible and financially sustainable. Businesses need to adopt circular metric frameworks such as the Global Circularity Protocol and Circular Transition Indicators to set clear, measurable goals for the transition. This will provide clarity to both internal and external stakeholders about their commitment to reducing material use, promoting the reuse of products, and enhancing transparency—whilst remaining competitive. Through clearly defined resource targets tied to business strategy and operations, businesses can demonstrate tangible progress on their circular economy journey while aligning their operations with sustainability goals.

Invest in the circular economy now to ensure that they remain competitive and future-proof. Transitioning to circular models provides new market opportunities. By investing in renewable resources, sustainable production technologies, reverse logistics infrastructure, and circular product design, businesses can secure long-term success, enhance their competitive edge, and reduce risks related to geopolitical matters, resource scarcity and regulatory changes. Rethinking product portfolios to align with circular principles—such as designing for durability, repairability, and recyclability—will be key to adapting to evolving market demands. The global economy is now facing increasing supply chain disruptions, particularly for the critical raw materials essential to decarbonisation and digitalisation, as well as a number of key manufacturing industries. With escalating demand, businesses that integrate circular strategies and localise their operations can shorten supply chains and ultimately reduce dependence on global markets. Circular business models can drive value through cost reduction, resource efficiency, and innovation, and the metrics used to track these activities—such as circular inflow (the use of recycled materials), circular outflow (end-of-life management), and waste/resource consumption avoided—will be essential to evaluate and scale their impact.

Collaborate and work together within value chains to optimise resource use and drive innovation. Businesses should collaborate across the full value chain to optimise material use and overcome economic split incentives. By joining forces with suppliers, manufacturers, and other partners, companies can drive innovation and invest in the changes needed to make circular solutions viable. Collaboration helps to build economies of scale, reduce costs, and share knowledge, ultimately accelerating the adoption of circular practices across entire industries. In doing so, businesses can also address the risks inherent in the current linear economy, such as supply chain disruptions, resource scarcity, and increasing regulatory burdens. By working together to shift to circular solutions, companies can unlock opportunities to create new markets, optimise materials use, and ensure long-term resilience.

Appendix A: *Glossary*

Accumulated Stock measures the total volume of materials added to socioeconomic stocks over time.

Cascading is a method of retaining the 'added value' of materials for as long as possible through the sequential use of resources for different purposes—usually (or ideally) through multiple material (re) use phases before energy extraction/recovery operations. [Source]

Consumption refers to the usage or consumption of products and services meeting demand. *Absolute consumption* refers to the total volume of either physical or monetary consumption of an economy, domestic or global, as a whole. In this report, when we talk about *consumption*, we are referring to absolute consumption.

Cycling refers to the process of converting a material into a material or product of a higher (upcycling), same (recycling) or lower (downcycling) embodied value and/or complexity than it originally was.

Decoupling refers to a trend that occurs when the growth rate of an environmental impact (for example, CO_2 emissions) is less than that of its economic driving force (for example, gross domestic product) over a given period. Decoupling can be either absolute or relative. **Absolute decoupling** is defined as when the environmental impact is stable or decreases when the economic driving force is growing. **Relative decoupling** is defined as when the growth rate of the environmental impact is positive but less than the growth rate of the economic driving force. [Source]

Domestic Material Consumption is an environmental indicator that covers the flows of both products and raw materials by accounting for their mass. It can take an 'apparent consumption' perspective—the mathematical sum of domestic production and imports minus exports—without considering changes in stocks. It can also take a 'direct consumption' perspective, in that products for import and export do not account for the inputs—be they raw materials or other products—used in their production. [Own elaboration based on Source]

Economy-wide material flow accounts is a 'statistical accounting framework describing the physical interaction of the economy with the natural environment and with the rest of the world economy in terms of flows of materials.' [Source]

Greenhouse gases (GHG) refers to a group of gases contributing to global warming and climate breakdown. The term covers seven greenhouse gases divided into two categories. Converting them to **carbon dioxide equivalent** (CO_2e) through the application of characterisation factors makes it possible to compare them and to determine their individual and total contributions to Global Warming Potential (see below). [Source]

Gross Additions to Stock measures the total amount of materials used in long-lived applications (of over one year) in the accounting year. In the context of this analysis, this can include both virgin and secondary materials.

High-value recycling refers to the extent to which, through the recycling chain, the distinct characteristics of a material (the polymer, the glass or the paper fibre, for example) are preserved or recovered so as to maximise their potential to be re-used in a circular economy. [Source]

Materials, as referred to in this report, are non-metallic minerals, metal ores, biomass, and fossil fuels, used as inputs to production or manufacturing because of their properties. Materials are a type of natural resource, alongside land and water, for example.

Material extraction is an environmental indicator that measures, in physical weight, the amount of raw materials extracted from the natural environment for use in any economy. It excludes water and air. At the national level, this indicator is called Domestic Material Extraction. [Source]

Material footprint, also referred to as Raw Material Consumption, is the attribution of global material extraction to the domestic final demand of a country—referred to as a **consumption-based approach**. The material footprint equals the total volume of virgin materials embodied within the supply chain to meet final demand. At the global level, Raw Material Consumption is equivalent to material extraction (see above). [Source]

Material flows represent the amounts of materials in physical weight that are available to an economy. These material flows comprise the extraction of materials within the economy as well as the physical imports and exports (such as the mass of goods imported or exported). Air and water are generally excluded. [Source]

Net Additions to Stock measures the net amount of materials long-lived applications after accounting for materials removed from existing Accumulated Stocks through Demolition and Discard. This flow only contains virgin materials, as the amount of secondary materials in both Gross Additions to Stock and Demolition and Discard is assumed to be equal within the same accounting year.

Planetary boundaries define the 'safe operating space' for humanity based on the planet's key biophysical processes. Originally developed by Rockström et al. (2009), the framework quantifies nine 'limits' for ensuring a stable and resilient Earth system. Six of nine boundaries have now been transgressed. [Source]

Resources include, for example, arable land, freshwater, and materials. They are seen as parts of the natural world that can be used for economic activities that produce goods and services. Material resources are biomass (like crops for food, energy and bio-based materials, as well as wood for energy and industrial uses), fossil fuels (in particular coal, gas and oil for energy), metals (such as iron, aluminium and copper used in construction and electronics manufacturing) and non-metallic minerals (used for construction, notably sand, gravel and limestone). [Source]

Resource efficiency means creating more (economic) value with less input of resources (for example, raw materials, energy, water, air, land, soil, and ecosystem services) and reducing the environmental impacts associated with resource use to break the link between economic growth and the use of nature. Therefore, resource efficiency is closely linked to the concept of (relative/absolute) decoupling. [Source]

Secondary materials are materials that have been used once and are recovered and reprocessed for subsequent use. This refers to the amount of the outflow that can be recovered to be re-used or refined to re-enter the production stream. One aim of dematerialisation is to increase the amount of secondary materials used in production and consumption to create a more circular economy. [Source]

Sufficiency, as defined by the IPCC, is a set of policy measures and daily practices that avoid demand for energy, materials, land, water, and other natural resources while delivering human wellbeing for all within planetary boundaries. [Source]

Total material consumption is calculated by adding Raw Material Consumption (material footprint) and secondary material consumption (cycled materials).

Endnotes

1. Note that the use of 'we' and 'our' throughout this report often refers to Circle Economy, this report's author, with the exception of the use of the general societal 'we'.
2. International Resource Panel (IRP). (2024). *Global Resources Outlook 2024: Bend the trend: Pathways to a liveable planet as resource use spikes*. United Nations Environment Programme: Nairobi. Retrieved from: UNEP website
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25. Circle Economy analysis.

26. Circle Economy analysis.

27. Circle Economy analysis.

28. Due to data limitations, it is assumed that waste destined for recycling is a good proxy for secondary materials that will be deployed in the economy within the accounting year, according to Eurostat (page 12). In reality, there are time lags and inefficiencies in the waste management system: this means that the amount of waste available for recycling and the secondary materials flowing into the economy in the same year are not necessarily the same.

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30. This analysis attributes 'material handling and use' to all final uses that serve material purposes: for example, energy use in freight transport and non-residential buildings is classified as serving material purposes because these activities directly support the movement and sale of goods. It's important to note that other research takes a narrower scope in linking material use and emissions, with the International Resource Panel, for example, estimating that 23% of emissions are linked to the 'production of materials'. From source.

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33. This number excludes combustion-related solid and liquid waste, such as ashes and sludges.

34. This number excludes combustion-related solid and liquid waste, such as. ashes and sludges. This share of waste out of Processed Outputs may therefore be slightly underestimated.

35. The difference between this figure and the recycling rate as calculated with the Sankey data (27.7%) is due to slightly different totals for waste generation following the harmonisation and reconciliation of different data sources. We report on the actual result from the database for a consistent comparison with 2018 data.

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140. Circle Economy analysis.

141. Circle Economy analysis.

142. Circle Economy analysis.

143. Circle Economy analysis.

144. This goal stems from Circle Economy's research conducted for the *Circularity Gap Report 2021,* which found that circular strategies applied across key sectors could reduce material use by approximately one-third and boost the Circularity Metric to 17%.

145. Target based on: Fanning, A., O'Neill, D., Hickel, J., & Roux, N. (2022) The social shortfall and ecological overshoot of nations. *Nature Portfolio.* doi:10.1038/s41893-021-00799-z

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147. Target based on: UNEP. (2022). *Emissions gap report 2022.* Retrieved from: UNEP website

148. Target based on: Fritsche, U., Brunori, G., Chiaramonti, D., Galanakis, C., Matthews, R. & Panoutsou, C. (2021). *Future transitions for the bioeconomy towards sustainable development and a climate-neutral economy - foresight scenarios for the EU bioeconomy in 2050*. Luxembourg: Publications Office of the European Union. doi:10.2760/469550, JRC123532.

149. Target based on: Bringezu, S. (2015). Possible target corridor for sustainable use of global material resources. *Resources, 4*(1), 25-54. doi: 10.3390/resources4010025

150. Prominent examples of measurement frameworks and reporting standards that can guide businesses in measuring their circular economy performance include the Circular Transition Indicators (CTI), the European Sustainability Reporting Standard on Resource Use and Circular Economy (ESRS E5), the GRI 301 and 306, and ISO 59020. Harmonisation efforts across these standards are also underway by the development of the Global Circularity Protocol by the WBCSD and the UN One Planet Network.

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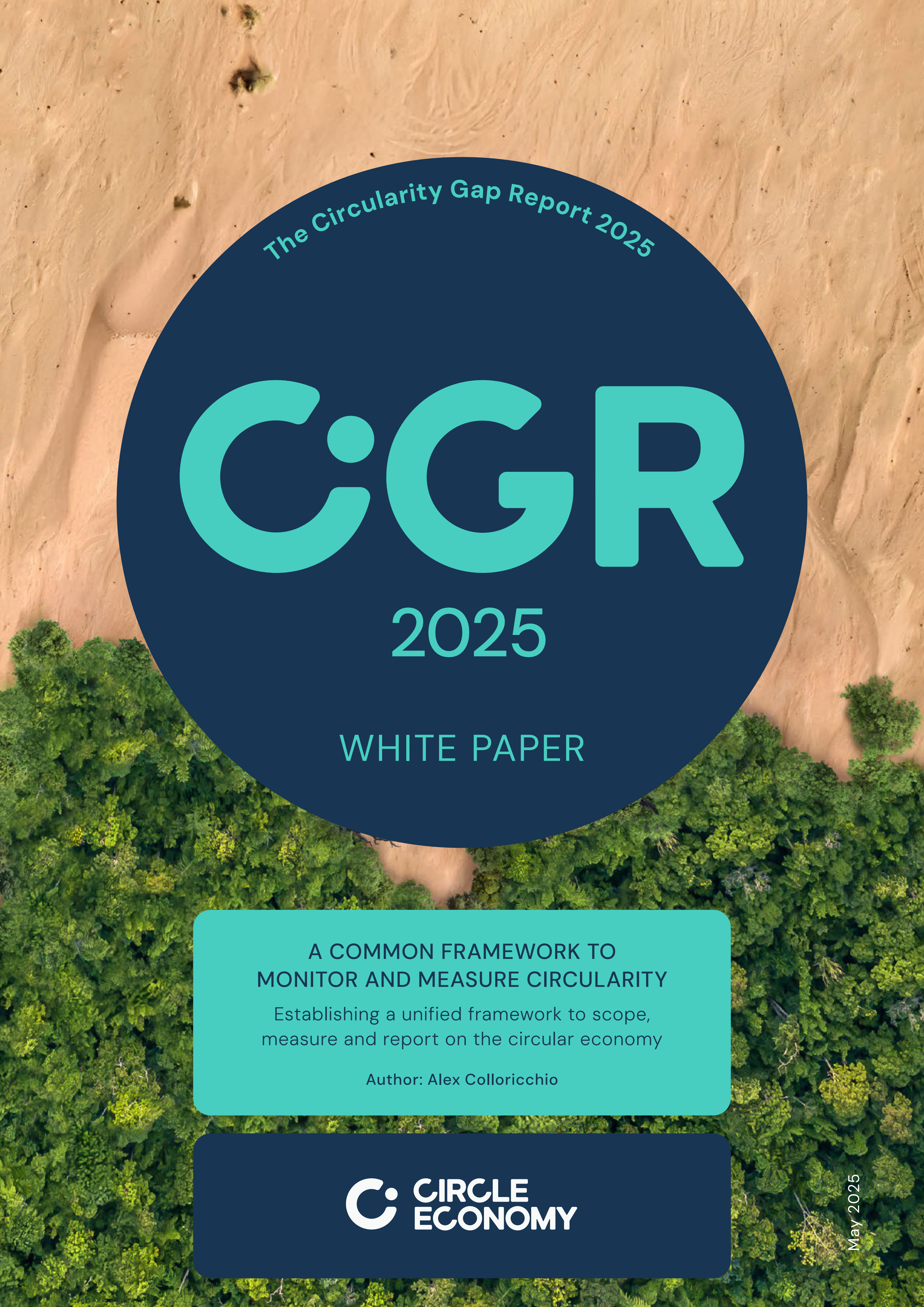

The Circularity Gap Report 2025

CGR 2025

WHITE PAPER

A COMMON FRAMEWORK TO MONITOR AND MEASURE CIRCULARITY

Establishing a unified framework to scope, measure and report on the circular economy

Author: Alex Colloricchio

CIRCLE ECONOMY

May 2025

CONTENTS

ABOUT CIRCLE ECONOMY

Circle Economy is driving the transition to a new economy. In this economy we help businesses, cities and nations leverage business opportunities, reduce costs, create jobs and inspire behavioural change. As a global impact organisation, our international team equips business leaders and policymakers with the insights, strategies, and tools to turn circular ambition into action.

Circle Economy has been at the forefront of the circular economy transition since 2012. Our annual *Circularity Gap Report* sets the standard for measuring progress and we manage the world's largest circularity database, encompassing data from over 90 nations, 350 cities, and 1,000 businesses.

1. INTRODUCTION

The *Circularity Gap Report 2025* provides a comprehensive progress report on the state of the global circular economy. With the understanding that the circular economy transition is about more than just recycling, the report opens up the 'Circularity Gap', providing a wealth of headline and sub-indicators to support the Circularity Metric—measured by Circle Economy since 2018. It presents and builds on the Circularity Indicator Set, a dashboard of 11 indicators, incorporating beneficial aspects of other leading frameworks: *ISO/DIS 59020:2023(E): Circular Economy—Measuring and Assessing Circularity* and the *Conference of European Statisticians Guidelines for Measuring Circular Economy, Part A: Conceptual Framework, Indicators and Measurement Framework*. This complementary white paper gives deeper insight into the Circularity Indicator Set, explores the structure and scope of the two additional frameworks, and lays out how we've incorporated these in our work.

2. UNPACKING THE CIRCULARITY INDICATOR SET

The Circularity Indicator Set is a system of tiered indicators designed to measure how circular an economy is. This indicator set and its underlying measurement framework, which are explored in more depth in the methodology document of the *Circularity Gap Report 2025*, has been historically used by and built upon by Circle Economy to provide insight into all inputs and outputs of an economy. Our 'Circularity Metric'—or Input Technical Cycling rate—is perhaps the most well-known of these indicators. Collectively, the Indicator Set examines the relationships between resources we take from nature, how we use them, and their impact on the environment. In alignment with the System of Environmental-Economic Accounts Central Framework (SEEA-CF), this framework is centred on the idea of a socioeconomic system that rests 'inside' the environment, with materials flowing between and within the two. Although this analysis has a global scope, the measurement framework can be set up at the (multi- and sub-)national level to account for trade and the movement of materials between nations, which is important when assessing environmental footprints. Circle Economy supports national and regional economies in using the Circularity Indicator Set for analysis, but is also using it for targeted assessments, such as for industries: the *Circularity Gap Report Textiles,* launched in 2024, for example. The Indicator Set can also be adapted for analysis at the product level. This flexibility comes from its tiered structure, which allows for detailed or broader analysis depending on the context. The Indicator Set relies—as much as possible—on highly-harmonised and regularly updated data, ensuring accurate comparisons between countries and enabling the consistent monitoring of progress toward a circular economy. This framework lends itself well to integration with other leading indicator frameworks for the circular economy, discussed in the following section.

The Circularity Indicator Set is grounded in the SEEA-CF, and its subsystem of Economy-Wide Material Flow Accounts (EW-MFA), and builds upon leading academic work in the field of industrial ecology.[1 2 3 4] It expands on the scope of traditional EW-MFA, providing a more comprehensive measure of the scale and circularity of total material and waste flows. This comprehensive measure is enabled by core features of the Set, discussed in more detail below:

- The distinction between **rate** and **scale** indicators to measure circularity at both the input and output side;
- The distinction between **technical** and **ecological** cycles;
- The distinction between **natural** and **anthropogenic** flows;
- The distinction between material **flows** and **stocks.**

Rate and scale indicators. Rate indicators, expressed as percentages of a total, measure the 'circular performance' of an economy. An Input Technical Cycling rate (Circularity Metric) of 0% represents a fully linear economy, while a rate of 100% represents a (thermodynamically unfeasible) perfect circular economy, where all processed materials are cycled without losses. Each indicator in the Set is also ascribed a 'scale' figure, which expresses the material use as an absolute value. Rate and scale indicators are measured at both the input and output side (see Table one).

Technical and ecological cycling rates. The technical cycle refers to the processes that products and materials flow through in order to maintain their highest possible value at all times. It involves finite materials (alongside small amounts of biomass that enter the technical cycle) that are not consumed during use and industrial processes such as reuse, refurbishment, remanufacturing and recycling. In the *Circularity Gap Report* approach specifically, it includes recyclable end-of-life waste handled by waste management (on the output side) and reintroduced into the market as secondary materials (on the input side) - as well as reused products and by-products that are cycled without becoming waste. It does not include flows related to other processes that extend product lifetimes such as repair, sharing, refurbishment or remanufacturing. The ecological cycle refers to the processes—such as composting and anaerobic digestion—that collectively help regenerate natural capital. It involves renewable materials that can decompose and reintegrate into natural cycles, preferably regenerating and at the very least without harming ecosystems. In the *Circularity Gap Report* approach specifically, it refers to the flow of carbon-neutral biomass and the resulting outflows to the environment, which re-enter global biogeochemical cycles and are separate from the technical system. Both rates—referring to technical and ecological cycling—are based on the same system definitions and measured against the same reference flow: processed materials, whether for input or interim output.. This shared denominator ensures that the rates are consistent, mutually

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[1] Mayer, A., Haas, W., Wiedenhofer, D., Krausmann, F., Nuss, P., & Blengini, G. A. (2018a). Measuring progress towards a circular economy: A monitoring framework for economy-wide material loop closing in the EU28. *Journal of Industrial Ecology*, *23*(1), 62–76. doi:10.1111/jiec.12809
[2] Haas, W., Krausmann, F., Wiedenhofer, D., & Heinz, M. (2015). How circular is the global economy?: An assessment of material flows, waste production, and recycling in the European Union and the World in 2005. *Journal of Industrial Ecology*, *19*(5), 765–777. doi:10.1111/jiec.12244
[3] Haas, W., Krausmann, F., Wiedenhofer, D., Lauk, C., & Mayer, A. (2020). Spaceship Earth's odyssey to a circular economy - a century long perspective. *Resources, Conservation and Recycling*, *163*, 105076. doi:10.1016/j.resconrec.2020.105076
[4] Haas, W., Virág, D., Wiedenhofer, D., & von Blottnitz, H. (2023). How circular is an extractive economy? South Africa's export orientation results in low circularity and insufficient societal stocks for service-provisioning. *Resources, Conservation and Recycling*, *199*, 107290. doi:10.1016/j.resconrec.2023.107290

exclusive, and additive, meaning they can be combined without overlap. It also makes them applicable at different scales, from sector-level analyses to global assessments.

Natural and anthropogenic flows. Natural flows are resources (such as extracted raw materials on the input side) or residuals (discharged waste and emissions on the output side) that originate from or are destined to return to the environment. Notably, natural flows can include both ecological, potentially-renewable materials, as well as inert non-renewable ones, such as metals, non-metallic minerals and fossil fuels. Anthropogenic flows, by contrast, originate from or are destined to return to socioeconomic systems. While natural flows contain only resources, anthropogenic flows can also contain man-made manufactured or semi-manufactured products in addition to resources. This distinction is particularly relevant in the context of trade and the calculation of Raw Material Equivalents[5] in material footprinting.

Flows and stocks. Activities in the socioeconomic system[6] are fed by flows of materials: these come from the natural environment, are processed by industries, and are then either accumulated in physical stocks or transformed and released back into the environment as waste or emissions. Materials added to stocks—like buildings, infrastructure, and durable goods like machinery, equipment and vehicles—are represented by the indicator Net Additions to Stock. This indicator measures the physical growth of an economy, and exposes the time lag between material consumption and waste generation. Although circular activities like repair, remanufacturing and sharing are not explicitly captured by the Circularity Indicator Set, their impact is implicitly captured by Net Additions to Stock: we would expect to see an increase in the service lifetimes of in-use stocks and potentially a stabilisation in the growth of in-use stocks.

Table one provides values for each headline indicator on the input and output side for 2021, the year of latest available data.[7]

	Indicator	Input		Output	
		Rate (%)	**Scale (billion tonnes)**	**Rate (%)**	**Scale (billion tonnes)**
Circular material flows	Technical Cycling rate	6.9%	7.3	11.2%	7.3
	Ecological Cycling Potential rate	21.5%	22.8	35.5%	23.2
Linear material flows	Non-Renewable Biomass rate	2.2%	2.3	3.4%	2.2
	Non-Renewable Flows rate	18.1%	19.2	28.6%	18.8

[5] Raw Material Equivalents refers to all the materials used to manufacture each component of a product. For example, a smartphone may only weigh a couple hundred grams, but requires far more resources to produce.
[6] Socioeconomic systems are large systems with people at the core, including social, economic, scientific, technological, and ecological environment fields, involving various aspects of human activities and the many complex factors of the living environment.
[7] Circle Economy analysis.

	Indicator	Input		Output	
		Rate (%)	Scale (billion tonnes)	Rate (%)	Scale (billion tonnes)
	Non-Circular Flows rate	13.3%	14.1	21.6%	14.2
Net stock build-up	Net Additions to Stock	38.0%	40.3	n/a	n/a

Since the launch of the first *Circularity Gap Report* in 2018, Circle Economy has endeavoured to analyse circularity, first for the globe and now for numerous countries, regions, cities and industries. As we've explored different themes linked to the circular economy—from climate breakdown and the planetary boundaries to jobs and well-being—we've continually strived to further develop and improve upon the Circularity Indicator Set, based on leading academic work. Improvements include:

- The systematic inclusion of trade flows for recycled waste and by-products, following Eurostat's Circular Material Use Rate methodology, as well as trade flows of reused products when national data is available;
- Accounting for domestically consumed by-products and reused products based on national sources, if accessible;
- The integration of indirect flows, or the upstream raw material requirements of trade, allowing for indicators to be calculated using both apparent consumption (Domestic Material Consumption) and material footprint (Raw Material Consumption);
- Cross-checking and reconciling results from the traditional and extended EW-MFA approaches to ensure robust and consistent outputs.

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3. OTHER LEADING INDICATOR FRAMEWORKS

ISO/DIS 59020:2023(E): Circular Economy—Measuring and Assessing Circularity

The recently published ISO/DIS 59020:2023(E) *Circular Economy—Measuring and Assessing Circularity* document, created by the International Organisation for Standardization (ISO), is the first authoritative effort to standardise quantitative assessments of the circular economy. It is part of the broader ISO 59000 series, which establishes shared terminology, principles, and guidelines to help organisations effectively implement circular strategies. This series also includes ISO/DIS 59004 *Circular Economy—Terminology, Principles and Guidance for Implementation*, for example, discussed in more detail below. The ISO standard provides guidance for evaluating circularity, promoting sustainable resource management, and encouraging transparency in reporting. While the ISO/DIS 59020 standard is largely *operational*—meaning it's centred on boundary setting, data acquisition, quality assurance, and documentation and reporting—it also establishes a *measurement* framework along with 14 core circularity indicators (learn more about types of frameworks in the text box on page 10).

These indicators take a multilevel perspective, pertaining to **systems** (regions, organisations, and products), **structures** (subsystems, sub-regions, and functional units, for example) and circular **activities** (such as reuse, repair, and so on). Indicators are also structured along four categories: energy, water, economic value, and inflows and outflows of resources. Resource indicators categorise inflows and outflows into four mutually exclusive types—recycled, reused, virgin renewable, and virgin non-renewable—which prevents overlap and adds up to 100%. The framework also factors in stocks—which remain in use over time—though this is done as a separate indicator, assessing product lifetimes in comparison to industry averages rather than fully integrating stock levels into material flow calculations.

The ISO/DIS measurement framework and indicator set are both relatively simple. The measurement framework defines the system being analysed in terms of its level, structure, and actions. The system in focus is embedded into environmental and social systems, with a few general flows describing how they interact with each other: 'primary resource inflows' represents the sourcing of materials from the environment, for example, while 'non-circular resource outputs' represents the outflow of materials to the environment. Inflows and outflows can also be considered 'circular' depending on the system boundary they cross: they can be internal, staying within the system in focus (reprocessing of scrap, for example), re-entering from the socioeconomic system (through recycling, for example), or re-entering from the environmental system (through composting, for example). In this framework, trade flows and interactions with other 'systems'—such as other national economies—are not specified.

ISO/DIS 59004 *Circular Economy—Terminology, Principles and Guidance for Implementation,* separate from the measurement framework, lays out terms and definitions, transitioning principles, and general practical aspects of shifting to a circular economy. While this is useful for organisations to understand and contribute to circularity, it does not systematically or structurally organise the indicators proposed in the standard. In the ISO/DIS 59020 standard, five categories of core indicators—resource inflows, resource outflows, energy, water, and value—are not directly addressed by the document. It instead largely centres on general principles organisations should align with—system thinking and value creation, for example—and actions they should carry out, such as design for circularity, repair, and recycling. What's more, although the standard acknowledges the interconnectedness of economic, social, and environmental systems and suggests complementary methods for impact assessment, it lacks a structured, interlinked framework for measuring circularity. Critical aspects like environmental impact, employment effects, supply security, and policy considerations are mentioned but not integrated into a cohesive measurement approach. As a result, the ISO 59000 series serves as a conceptual foundation but falls short of offering a comprehensive indicator framework for the circular economy.

UNECE/OECD: *Conference of European Statisticians Guidelines for Measuring Circular Economy—Part A: Conceptual Framework, Indicators and Measurement Framework*

This document, prepared jointly by the United Nations Economic Commission for Europe (UNECE) and the Organisation for Economic Co-operation and Development (OECD), is among the most comprehensive publications on measuring circular progress at the national level. Its headline definition captures the core principles shared across circular economy models: maximising the value of materials for as long as possible, minimising material input and consumption, preventing waste, and reducing negative environmental impacts throughout a material's life cycle. Contrary to the ISO standard, the UNECE/OECD guidelines also offer a *conceptual* framework (see text box on page 10), and combines the main features of a circular economy—such as the four flows*[8] [9]—with the basic principles of environmental accounting and reporting.[10] [11] [12] All dimensions of the circular economy—including physical, environmental, and systemic aspects across the entire lifecycle of materials, products, and services—are covered. *Core* indicators are structured according to four main so-called 'building blocks': **the material life cycle and value chain, interactions with the environment, socioeconomic opportunities,** and **responses and actions** (including innovation, regulatory and other instruments, and education, for example).

Each building block has a subset of themes and topics that provide an increasing level of detail, with each theme and topic having its own set of *complementary* and *contextual* indicators.[13] The full set comprises 16 core indicators (plus 5 placeholders for situations where no suitable indicator can be identified), more than 70 complementary indicators, and 13 contextual indicators.[14] While these all fit within one overarching conceptual and measurement framework, they still act as stand-alone indicators for a broad range of interlinked topics; however, while this set comprehensively covers all aspects relevant to the circular economy, it lacks a common denominator, meaning that indicators may use different units, methods or scales. This fundamental difference between indicators means that they lack a common basis for comparison or aggregation, making it difficult to integrate into a cohesive whole.

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[8] Potting, J., Hanemaaijer, A., Delahaye, R., Ganzevles, J., Hoekstra, R. & Lijzen, J. (2018). *Circular Economy: What we want to know and can measure. Framework and baseline assessment for monitoring the progress of the circular economy in the Netherlands.* The Hague: PBL, Netherlands Environmental Assessment Agency. Retrieved from: PBL website

[9] Bocken, N. M., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320. doi:10.1080/21681015.2016.1172124

[10] UN, EU, FAO, IMF, OECD, & WB. (2014). System of Environmental-Economic Accounting 2012 — Central framework. Retrieved from: SEEA UN website

[11] UNEP. (2021). *The use of natural resources in the economy: A global manual on economy wide material flow accounting.* Nairobi, Kenya. Retrieved from: IRP website

[12] OECD. (1993). *Core set of indicators for environmental performance reviews.* Environmental Monograph, 83.

[13] For example, the 'material life cycle and value chain' building block is divided into three themes: the first of these 'The material basis of the economy—production, consumption, accumulation" is further divided into three topics, 'Material inputs', 'Material consumption' and 'Accumulation'. A number of indicators is characterised for each.

[14] Core and complementary indicators are related to each other: for instance, the 'National recycling rate' indicator is related to the 'Waste going to final disposal', 'Circular material use rate', and 'Ratio of products repaired or reused to new products sold' indicators. However, the link between them is underspecified, posing a number of questions: are they calculated using the same or similar metrics? Where and how do they differ? Do they overlap?

* The four flows of the circular economy are **narrow** (use less), **slow** (use longer), **cycle** (use again), and **regenerate** (make clean), as developed by Bocken et al. (2016).

As noted, the OECD/UNECE guidelines first define a *conceptual* framework, within which the *measurement* framework is embedded. Notably—and in contrast to the ISO/DIS standard—the guidelines explicitly cover the interactions between the system in focus (a national economy, for example) with other economies and their environments. It considers the cross-border impacts between socioeconomic systems, particularly those linked to trade and their effects on natural assets and environmental quality both domestically and internationally.

The 'material life cycle and value chain' building block is the core of measuring the circular economy. It is first translated into simple measurement concepts comparable to those given by the ISO/DIS 59020 framework. Next, the framework is expanded to focus on interactions between the production and consumption system with the waste management system and other more informal waste management activities.

Understanding different types of frameworks

What to measure: A *conceptual framework*, such as that offered by the UNECE/OECD guidelines, helps structure the selection of indicators to ensure all important aspects of the circular economy are covered. It reflects the integrated, cross-cutting nature of the circular economy and organises indicators in a way that's practical and accessible for decision-makers and the public.

How to measure it, from a data perspective: A *measurement and monitoring framework*, offered by both the ISO standard and UNECE/OECD guidelines, helps to structure and combine underlying data, link circular economy concepts and definitions to the terms and definitions used in official statistics, and ensure that data sets are coherent. These benefit policymakers by providing reliable, comparable and comprehensive data and indicators to support informed decision-making.

How to measure it, from a process perspective: An *operational framework*, such as that offered by the ISO standard, tells us *how* to measure circularity by providing rules, procedures and guidelines on the processes underlying the development and use of indicators. It can be used to implement measurement efforts, replicate standardised results and compare them.

4. INTEGRATING THE CIRCULARITY INDICATOR SET AND OTHER LEADING FRAMEWORKS

Each of the leading frameworks discussed above brings its own benefits. The UNECE/OECD's conceptual and measurement frameworks offer structure and comprehensiveness—although the related indicator set lacks a common denominator. The ISO approach of offering mutually exclusive indicators with a shared common denominator provides cohesiveness and unity, but lacks the comprehensiveness of the UNECE/OECD frameworks. The Circularity Indicator Set exhibits the beneficial aspects of each, offering a cohesive and comprehensive framework suitable for many aims: the headline indicators, for example, are useful for raising awareness and communicating circular progress to a more general audience, while lower-tier indicators can provide government officials, policy analysts and other technical stakeholders with the in-depth information needed to support decision making and agenda setting. The Set's alignment with the UNECE/OECD guidelines and the ISO standard ensures that it both fits into a broad and holistic approach to measuring circularity while complying with emerging standards on the topic. To this end, a full evaluation of the relationship between the Circularity Indicator Set, ISO standard and UNECE/OECD framework—which explores their coverage and alignment—is available in Tables two and three.

Table two summarises the key elements of the ISO/DIS 59020:2023(E) standard and its alignment with the CGR methodology.

Element	Coverage/ Alignment	Notes
Measurement dimensions and levels of application	Partial	'*The framework is applicable to multiple levels of an economic system, ranging from regional, inter-organisational, organisational to the product level*.' While the ISO standard is focused on the organisational (micro) level, the CGR methodology is focused on the regional, national and supranational (meso and macro) level.
Three-step operational framework entailing: *Boundary setting, circularity measurement and data acquisition and circularity assessment and reporting*	Partial	While *Boundary setting* is inherently covered (ensuring appropriate boundaries and meaningful outcome), certain elements of the circularity measurement, data acquisition, assessment and reporting are not. For instance, '*appropriate indicators of value with careful consideration of its retention, recovering or addition to resource value or restoration (e.g. regeneration of ecosystems*' is not covered. Specific goals for data quality requirements are not formulated or explicit provision for public disclosure of comparative assertions are not made.
Circular goals, aspects and actions	Partial	*Goals* can be set in scenario modelling in the form of normative targets to explore their broader environmental (and social) implications. *Actions* (e.g. 9R strategies, composting, energy recovery) are included in the CGR scope by the *circular strategies* and reflected in the scenario modelling framework. *Aspects* (e.g. durability, recyclability, repairability) relate to qualitative characteristics of flows which are typically not

		considered in either baseline nor scenario assessments.
Circular measurement taxonomy	Partial	The *Resource flow measurement* principle defined as 'resource inflows and outflows crossing boundaries of the system in focus (including losses and emissions)' is aligned with the EW-MFA economy-environmental boundary definition. *Circular categories and related indicators* are only fully covered for resource inflows and outflow. However, those for energy, water and economics are only partially aligned with the standard.
Measuring and assessing sustainability impacts	-	This is not covered by the standard itself, but a reference to other standards is made. The CGR methodology and models allow us to quantitatively address elements of the *social, environmental and economic impact & value*—however they are currently not reported (except for carbon footprint).
Resource inflows and outflows	Partial	'Sorting and processing losses' in the recycling process as the difference between inputs and output to the recycling operation are not quantified in CGR methodology. Inputs to the recycling plant are considered a proxy for the output from recycling plants in the current CGR methodology. This doesn't allow for a proper distinction between recyclable (output) and recycled (input) content. For stock additions (lifespan of more than one year) indicators of time such as average lifetimes are not covered by the CGR methodology (static approach).

Table three *summarises the key elements of the OECD/UNECE framework and its alignment with the CGR methodology.*

Element	Coverage/ Alignment	Notes
Aligned with *SNA* and *SEEA* frameworks	Full	*EW-MFAs, AEAs, IOTs* and the other building blocks of the CGR methodology are subsets of the SNA and SEEA framework and therefore highly aligned.
Four building blocks based on accounting and Bellagio	Partial	Only the *Material life-cycle and value chain* and elements of the *Socioeconomic opportunities*

principles and the pressure-state-response (PSR) model		component are currently included. The methodology and models allow us to quantitatively address elements of the *Interactions with the environment* component, however they are currently not reported (except for climate). The *Responses and actions component* is mostly addressed qualitatively.
Material life-cycle and value chain Theme one: *Interactions with trade and globalisation*	Full	Indicators on the level and characteristics of material supply and their use in the economy or in industries—particularly material inputs, consumption, and accumulation—as well as indicators that relate material use to GDP, value-added, or other socio-economic output variables through intensity or productivity ratios, are widely covered.
Material life-cycle and value chain Theme two: *Management efficiency of materials and waste, and the circularity of material flows*	Full	Indicators on waste generation, recycling rates, circular use rates, shares of secondary raw materials in material inputs or consumption; renewable content of material used in production processes, products diverted from the waste stream (repaired, remanufactured, reused), materials leaving the economic cycle, i.e. waste going to final disposal, are widely covered.
Material life-cycle and value chain Theme three: *Interactions with trade and globalisation*	Full	Indicators on exports and imports of materials, second-hand goods, end-of-life products and waste, the physical trade balance, and the material intensity of trade, are widely covered.
OECD environmental indicators 3-Tier structure based on relevance, measurability and usefulness	Full	The Circularity Indicator Set can be organised into a 3-Tier structure where the UNECE/OECD's core and complementary indicators (Tier 1 and 2) are both considered complementary (Tier 2) and contextual are the same.
Measurement dimensions and levels of application	Partial	The framework needs to be scalable to the interrelated levels the circular economy operates on the micro (e.g. products and companies), meso (e.g. sectors, industries, cities, sub-national governments) and macro level (i.e. national or supranational economies). While the CGR framework lends well to application to the macro and partially to the meso level, it is not particularly suited to the micro level.
Expanded versus traditional scope of waste	Partial	The CGR measurement framework covers all the elements of the UNECE proposed extended

statistics		scope of waste statistics. However, due to their exclusion from traditional waste statistics, the coverage is usually quite limited.

After years of providing a yearly check up on the global state of circularity—largely represented by a single metric—we're shifting gears: the *Circularity Gap Report's* goal is building out the Circularity Indicator Set to encompass the beneficial aspects of the other leading frameworks discussed. This first comprehensive and cohesive look at measuring the circular economy is explored in more depth in Chapter three of the *Circularity Gap Report 2025*, which presents the Circularity Indicator Set supported by relevant sub-indicators for changemakers drawn from the UNECE/OECD frameworks. Our focus is on converging the 'material life cycle and value chain' theme from the UNECE/OECD framework with the 'resource inputs' and 'resource outputs' categories from the ISO/DIS 59020 framework, providing a common language for two frameworks that measure similar metrics but otherwise use varying scales and terminology. In doing so, we benefit from applying the 'mutually exclusive' logic of the resource inputs and outputs categories to the statistical domain of environmental accounts (for example, material flow, emissions, waste, and water accounts), from which many UNECE 'material life cycle and value chain' indicators are derived. This allows us to consistently measure themes relevant to the circular economy—from the bioeconomy and energy transition to socioeconomic stocks—from both a material inflow and outflow perspective.

Barriers to fully integrating the ISO/DIS standard and the UNECE/OECD framework

The main barrier to fully integrating these work streams lies in a few fundamental differences in goals, scope and definitions. These are broadly summarised below:

- **Focus and application:** The ISO/DIS 59020 standard is product- and process-oriented, providing a technically precise framework for organisations conducting specific circularity assessments. In contrast, the UNECE/OECD guidelines take a broader, more flexible approach, focusing on systemic issues and enabling circular economy monitoring at regional and national levels.
- **Treatment of water and energy**: The UNECE/OECD framework accounts for water and energy only in terms of their interactions with the environment: water pollution or energy-related emissions, for example. However, it does not account for water or energy consumption per se. The ISO/DIS standard does the opposite: it accounts for water used in the processes under analysis and energy consumption in energy terms (i.e. kilowatt hours of electricity rather than tonnes of coal burnt), but does not explicitly cover their environmental impacts. Nonetheless, the sustainable use of freshwater and energy remains conceptually relevant to circular economy discussions.
- **Terminology and measurement**: The ISO/DIS standard broadly defines 'resources' as including raw materials, feedstocks, and components. The UNECE/OECD framework, however, uses more precise statistical classifications, distinguishing between natural resources, primary and secondary raw materials, and residuals. While both frameworks align conceptually, their terminology does not fully overlap. ISO prioritises

integration with other ISO standards for consistency, whereas UNECE/OECD follows the System of Environmental and Economic Accounts (SEEA) to bridge physical and monetary statistics. This accounting-based approach is well-suited for macro- and meso-level analysis but less effective for assessing specific product lifespans, material compositions, or production processes (for example, secondhand or bio-based materials).

In spite of these differences, the Circularity Indicator Set lends itself well to integration with both frameworks in terms of compliance (ISO) and superimposition (UNECE/OECD). The Circularity Indicator Set takes the same approach as the ISO standard, dividing resources into mutually exclusive categories: recycled and reused, virgin renewable, and virgin non-renewable materials. While the ISO standard was designed to apply this logic primarily at the product or organisational level, the Circularity Indicator Set scales it up for application at the national level, creating headline indicators in both the input (materials entering the economy) and output (waste and emissions) side of the system under study. In order to better comply with the ISO standard, we have introduced a number of other methodological modifications to the Circularity Indicator Set: these are explored in detail in the text box below.

Modifications to the Circularity Indicator Set made by Circle Economy

1. Differentiating between 'Recycled/Reused' and 'Recyclable/Reusable' materials: The ISO/DIS 59020 standard requires that recycling and reuse are measured on both the input and output side:

Input: Measures the fraction of resources confirmed as recycled content, including pre- and post-consumer materials but excluding internal industrial reuse. Reuse is strictly defined as remanufacturing, excluding broader durability-related aspects like repair or refurbishment.

- Output: Estimates the fraction of outflow content that was (or is likely to be) recovered and recycled into secondary materials or reused in production, maintenance, or repair.

From an economy-wide perspective, this distinction allows us to differentiate between waste collected for recycling and actual secondary materials.[15] Waste collected for recycling is measured at the recycling plant gate, whereas secondary materials are tracked at their market deployment point. The difference reflects sorting and processing losses, meaning Eurostat's assumption that 'input to recovery plants is an acceptable proxy for output'[16] is no longer valid. These losses must now be explicitly quantified. Distinguishing between reused and reusable content remains challenging due to a lack of statistical data and an undeveloped methodology.

[15] This requires a common definition for 'recyclable' materials. 'Recyclability' is challenging to define, with technical and economic factors playing a role.
[16] Eurostat. (2018). *Circular material use rate – Calculation method. 2018 edition.* Manuals and guidelines. Retrieved from: [Eurostat website]

2. Defining and quantifying 'Sustainably Produced Renewable Content' and 'Recirculation—Safe Return to the Biosphere': The ISO/DIS 59020 standard defines renewable material as 'biomass that is replenishable at a rate equal to or greater than the rate of depletion,' with bio-based inflows considered circular only if they are sustainably managed. On the output side, the 'percent actual recirculation of outflow in the biological cycle' indicator measures the fraction of biomass or nutrients safely returned to the biosphere (for example, via composting or anaerobic digestion). These definitions align with the Ecological Cycling Potential indicator. While methodologies for systematically assessing the sustainability of biomass are still evolving, the economy-wide biogenic carbon balance approach by Haas et al. (2020)[17] serves as an initial proxy for estimating renewable biomass inputs and safe biological recirculation.

3. Aligning with a lifetime perspective on long-term products and materials: Measuring the relationship between physical stock, durability, and value retention is complex in a circular economy. The Circularity Indicator Set follows an EW-MFA approach, measuring stock additions based on mass using a static balance method that does not explicitly model how long products and embodied materials stay in use (technical lifetime) before becoming waste. The 'net stocking rate' (expressed as a percentage) is treated as a mutually exclusive inflow indicator. As noted previously, circular economy strategies such as product lifetime extension, renovation, and sharing can be indirectly observed through the potential stabilisation of in-use stock growth, as indicated by the Net Additions to Stock indicator. In contrast, the ISO/DIS 59020 standard measures a product or material's expected useful lifetime based on durability assessments that consider reliability and lifetime extensions through maintenance, repair, and refurbishment. This reflects a key difference:

- Circularity Indicator Set: Categorises material inflows and outflows by their destination (for example, stocked, technically cycled, or non cycled).
- ISO/DIS 59020: Classifies materials based on content (for example, virgin non-renewable, recycled), with 'stocked' not considered a separate flow type.

To comply with ISO/DIS 59020, the Circularity Indicator Set now includes a new indicator—'average lifetime of stock relative to the global average'—alongside the traditional net stocking rate. This sub-indicator offers a more detailed view of material accumulation, aligning with UNECE/OECD core indicators.

Some of the Set's indicators align directly with certain topics of the UNECE/OECD framework: for example, the Input Technical Cycling rate and Output Technical Cycling rate directly measure the topics 'Circularity of material flows' and 'Materials diverted from final disposal through recycling or recovery', respectively. Others, however, do so less directly. The Input Non-Renewable rate and Output Non-Renewable Rate, for example, account for the amount of potentially recyclable materials that are instead disposed of and can be used to measure the topic 'Materials leaving

[17] Haas, W., Krausmann, F., Wiedenhofer, D., Lauk, C., & Mayer, A. (2020). Spaceship earth's odyssey to a circular economy-a century long perspective. *Resources, Conservation and Recycling, 163*, 105076.

the economic cycle'. However, they are not suited to capturing the topic 'Waste generation (materials ending up as waste)'.

The framework also contains a number of indicators that provide considerably more information than the one-dimensional Indicator Set's headline indicators: for example, indicators that measure intensities (such as energy intensity), trends, and material composition breakdowns. The broader, multi-faceted coverage of the UNECE/OECD indicators offers more operationality, context and nuance to their measurement.

However, while some of these core and complementary indicators are not directly represented by the Indicator Set's headline indicators, they *are* necessary to calculate them. For instance, the Input Technical Cycling rate requires data on 'Demand-based raw material consumption (RMC)', 'National recycling rates' for both municipal solid waste (MSW) and special waste, and 'Trade in waste, secondary materials, secondary raw materials, second-hand goods'. Similarly, the Input Ecological Cycling Potential rate requires data on the 'Proportion of materials from renewable natural stocks in DMC' as well as 'Emissions and removals from land use, land-use change, and forestry'.

This configuration offers an ideal opportunity to superimpose the Circularity Indicator Set's headline indicators 'on top of' the relevant UNECE/OECD indicators, providing a cohesive higher-level set of headline indicators with underlying, complementary UNECE/OECD indicators—among others—to support, enrich and expand upon the headline measurements. In this setup, the Circularity Indicator Set's headline indicators serve as a simplified overview, while the UNECE/OECD indicators provide the detailed data needed to understand trends, variations, and broader implications. These form the headline and sub-indicators calculated and explored in Chapter three of the *Circularity Gap Report 2025.*

Table four lists the Circularity Indicator Set structure and its relationship with key elements of the CES Guidelines for Measuring Circular Economy, Part A: Conceptual Framework, Indicators and Measurement Framework (theme, topics, tiered structure) and the ISO/DIS 59020 standard (category, content, principle).

CES guidelines	**Themes**	**1) Material life cycle, value chain → production and consumption** **2) Interactions with the environment → environmental effectiveness**										
	Topics	1.1) Material basis of the economy: Production, consumption and accumulation 1.3) Interactions with trade										
		1.2.1) Circularity of material flows						1.2.2) Management efficiency of materials & waste				
		2.1) Natural resource implications						2.2) Environmental quality implications				
ISO standard	**Category**	Resource Inflows (I)					Accumulation	Resource Outflows (O)				
	Content	Recycled & Reused	Virgin Renewable	Virgin Non-Renewable**			Accumulation	Recycling & Reuse	Recirculat ion	Non-Recovered**		
	Principle	∑ = 100%						∑ = 100%				
CIS	**Headline indicators (Tier 1)**	Circularity (Circular material flows)		Circularity Gap (Linear material flows)			Circularity Lag (Stock build-up)	Circularity		Circularity Gap (Linearity)		
		(I)TCr	(I)ECPr	(I)NRBr	(I)NCr	(I)NRr	NSr	(O)TCr	(O)ECPr	(O)NRBr	(O)NCr	(O)NRr
	Compleme ntary indicators [18,19,20] **(Tier 2)**	**- DMC/I (tonnes)** **- RMC/I (tonnes)** - Secondary material consumption/I (tonnes)[21] **- Circular Material Use Rate (CMUR)**	- DMC biomass (tonnes) - RMC biomass (tonnes) - Reclamation rate of organic substances - Share of forested land - Land protection rate - Water protection rate[22] **- Water stress level**		- Total primary energy supply (EJ) - Share of electricity in final energy consumption - Share of renewable energy in final energy	- Self-suffici ency by raw material[25] - Material import dependenc	- NAS (tonnes) - Renewable biomass as a share of NAS - Growth rate of built-up area - Average lifetimes of asset	**- Recycling rate** - Waste collection rate - Waste as share of DPO	- LULUCF emissions[30] (tonnes) **- Safely treated wastewater flows**		**- GHG emissions[31] (tonnes)** - Emissions to air as share of DPO - Average	**- Total waste generation (tonnes)** **- Controlled/u ncontrolled disposal rate**

[18] Units are in % unless otherwise specified.
[19] Working list. Where possible and applicable—trends, mix and intensities—are included as per CES guidelines recommendations.
[21] Domestic use plus imports minus exports of waste destined to recycling, by-products and reused products.
[25] Not reported in the *CGR 2025* report because this is only relevant at the national level.
[30] Territorial and consumption-based perspectives.
[31] Territorial, production- and consumption-based perspectives.

			- Ecological overshoot[23]	consumption - Energy efficiency of asset categories[24] (various) - Fossil fuel subsidies (€)	y[26]	categories (years)[27] - Average 'R' rates of asset categories[28]	- Footprint index[29]		emission intensities of asset categories[32]	
	Contextual indicators[33] (Tier 3)									

* Blue = Technical Cycle, Green = Ecological Cycle

** Includes both potentially circular and inherently non-circular materials that are non-renewable and non-recoverable

[20] Corresponds to core and complementary CES guidelines indicators. Indicators marked in **bold** correspond to the CES guidelines' **core indicators (or proxies thereof)**.

[22] Not reported in the *CGR 2025*.

[23] Placeholder for core indicator 'Natural resource index/depletion ratios'. Not reported in the *CGR 2025*.

[24] Depending on the asset type, energy efficiency can be measured in different ways, for example: primary energy demand in buildings (MJ/km2), fuel efficiency in vehicles (lt/km) or energy efficiency in appliances (% or energy labels). Not reported in the *CGR 2025* due to lack of comprehensive data.

[26] Not reported in the *CGR 2025* report because this is only relevant at the national level.

[27] Placeholder for SO/DIS 59020:2023(E) 'lifetime ratio' indicator.

[28] 'R' rates refers to the different types of strategies for loop closing such as renovation, refurbishment, or remanufacturing which apply to different asset types such as buildings, appliances and equipment, or vehicles. Not reported in the *CGR 2025* due to lack of comprehensive data.

[29] Production- and consumption- based, according to Eurostat's approach for the cei_gsr010 indicator. Not included in the *CGR 2025* due to scope limitation.

[32] Depending on the asset type, emissions can be measured in different ways (for example, kgCO2/MJ, kgCO2/lt). Not included in the *CGR 2025* due to scope limitation.

[33] Contextual indicators were not explicitly reported in the *CGR 25.* However, they remain part of the framework.

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The Circularity Gap Report 2025

CGR 2025

METHODOLOGY DOCUMENT

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CIRCLE ECONOMY

May 2025

CONTENTS

LIST OF ACRONYMS

BIs: Balancing Items

CES: Conference of European Statisticians

CGR: Circularity Gap Report

CIS: Circularity Indicator Set

LRTAP: Long-Range Transboundary Air Pollutants

CN: Combined Nomenclature

DIS: Draft International Standard

DMC: Domestic Material Consumption

DPO: Domestic Processed Output

EW-MFA: Economy-Wide Material Flow Accounting

GAS: Gross Addition to Stocks

GHG: Greenhouse Gases

HS: Harmonised System

ISO: International Standard Organisation

LULUCF: Land Use and Land Use Change from Forestry

MSW: Municipal Solid Waste

NAS: Net Addition to Stocks

OECD: Organisation for Economic Cooperation and Development

PTB: Physical Trade Balance

RMC: Raw Material Consumption

RTB: Raw (Materials) Trade Balance

SEEA-CF: System of Environmental-Economic Accounts—Central Framework

SW: Special Waste

UNECE: United Nations Economic Commission for Europe

WaW: What a Waste

1. INTRODUCTION

1.1 The need for a global circularity benchmark

The transition to a circular economy is central to addressing resource depletion, environmental degradation and the general transpassing of planetary boundaries. However, achieving a truly circular economy requires a systematic, data-driven approach that measures and tracks material flows and stocks, waste generation and treatment rates at different scales—global, national, sectoral, and product-level. This document lays out the methodology used for the *Circularity Gap Report (CGR) 2025*. It provides a robust framework to measure material circularity, enabling policymakers, researchers, and businesses to assess progress and identify areas for improvement.

1.2 Purpose and scope of the *Circularity Gap Report 2025* methodology

The *CGR 2025* methodology is designed to:

- Benchmark material circularity at the global level, with annual updates to track progress over time;
- Provide a standardised Circularity Indicator Set (CIS) that quantifies the scale of material and waste flows and the rate of their reintegration into technical and ecological cycles;
- Ensure methodological alignment with key international frameworks, including the *Conference of European Statisticians (CES) Guidelines for Measuring Circular Economy, Part A: Conceptual Framework, Indicators and Measurement Framework* and the *ISO/DIS 59020:2023(E) Circular Economy Standard* to allow for comparability and transferability from the globe to other levels (national or industry or business);
- Extend beyond traditional recycling metrics by capturing:
    - The stock dynamics of materials (long-term material accumulations in infrastructure and products);
    - Trade implications, particularly the movement of secondary materials and waste across borders;
    - Technical and ecological cycling rates, distinguishing between materials that can be reintroduced into industrial systems and those that follow natural biogeochemical cycles.

The *CGR 2025* calculations draw from over 100 multilateral and national data sources, along with expert estimates and modelling techniques for data gap-filling, all of which is built into an extensive data infrastructure.

1.3 Conceptual and statistical foundations

The *CGR Measurement Framework* builds upon established industrial ecology and material flow accounting principles while expanding their scope to better capture the complexities of modern material flows.

The methodology integrates several key concepts. It:

1. **Distinguishes between scale and rate indicators:**
    - Scale indicators measure the absolute magnitude of material flows (for example, total material extraction, total waste generated).
    - Rate indicators assess the circular and non-circular performance of an economy, and are expressed as percentages of the total amount of materials flowing in and out of that economy (for example, the Circularity Metric, which measures the share of secondary material consumption out of total material consumption).
2. **Differentiates between input-side and output-side circularity:**
    - Input-side indicators measure the share of particular materials streams (e.g., secondary materials, carbon-neutral biomass) in total processed materials.
    - Output-side indicators assess how much waste is being effectively reintegrated into technical or ecological cycles.
3. **Accounts for technical and ecological cycles:**
    - Technical cycle refers to the processes that products and materials flow through in order to maintain their highest possible value at all times. It involves finite materials (with the exception of some biomass entering the technical cycle) that are not consumed during use and industrial processes such as reuse, refurbishment, remanufacturing and recycling.
    - Ecological cycle refers to the processes – such as composting and anaerobic digestion – that together help to regenerate natural capital. It involves renewable materials that can decompose and reintegrate into natural cycles - at least without harming and preferably regenerating - ecosystems.
4. **Incorporates trade and stock dynamics:**
    - Unlike traditional Economy-Wide Material Flow Accounts (EW-MFA) approaches, the *CGR* framework explicitly accounts for international trade in secondary materials and its implications for national circularity.
    - It also captures material stock accumulation, recognising that materials used for long-lived infrastructure and products delay waste generation and affect circularity rates.

This methodology document is structured as follows:

- **Section two explores the** CIS and defines the core indicators used to measure circularity, detailing their structure, scope, and alignment with international standards.

- **Section three** explains the *CGR Measurement Framework* and lays out the data sources, calculation methodologies, and statistical models underpinning the indicators.

- **Section four** breaks down the *CGR Measurement Framework* into specific thematic modules, covering:
    - Materials (extraction and trade)
    - Emissions (air, water, and land pollution)
    - Waste (generation and treatment)
    - Balancing items and stock additions

- **Section five** explores the way forward, detailing ongoing improvements, data enhancements, and methodological extensions planned for future iterations of the *CGR* Measurement Framework.

The *CGR 2025* methodology builds on the latest *CGR Methodology for Nations*[1] and the *CGR Latin America and the Caribbean*[2] methodology. Throughout this document, we refer to relevant sections from both of these methodology documents.

[1] Circle Economy. (2024). *The circularity gap report Nations: Methodology document (v 1.2)*. Amsterdam: Circle Economy. Retrieved from: CGRi website
[2] Circle Economy. (2023). *The circularity gap report Latin America and the Caribbean: Methodology document (v 1.0)*. Amsterdam: Circle Economy. Retrieved from: CGRi website

2. CIRCULARITY INDICATOR SET

The CIS is a system of tiered indicators—scoped out of a multi-thematic conceptual framework and grounded in a statistical measurement framework—that allows for a biophysical and economy-wide assessment of a circular economy, including flows-stocks relationships. In its current implementation, the scope of the CIS is centred on the material life cycle, the economy's production and consumption functions, and partly on their interactions with the environment in terms of natural assets and environmental quality implications.

The CIS's headline indicators are based on extended EW-MFA principles taken from the work of Mayer et al. (2018),[3] Haas et al. (2020)[4] and other prior research.[5, 6, 7] The underlying measurement framework fully integrates waste flows, recycling, and downcycled materials with traditional EW-MFA statistics. In the *CGR* model, the approach is further extended to include indirect flows, the trade of secondary materials, and other elements (see Section three). The CIS is designed for analysis at the macro-level (national, regional), however, it can also be applied at the meso- and micro-level by considering lower-tier indicators (or proxies thereof) that can be more suitable for sector- or product-level analysis. Given the statistical foundations of the underlying *CGR Measurement Framework*, the CIS calculation relies as much as possible on harmonised and regularly updated data, producing comparable results that are suitable for benchmarking across countries and that support consistent monitoring efforts.

For its headline indicators, the CIS distinguishes between scale indicators—which provide measures for the overall size of the socioeconomic metabolism—and rate indicators, which measure technical and ecological cycling relative to input and output flows. Providing independent measures for flows on both the input and output sides is necessary and insightful due to the delaying effect that in-use stocks of materials have on output flows. Table one lists the indicators and their definitions for the input- and output-side.

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[3] Mayer, A., Haas, W., Wiedenhofer, D., Krausmann, F., Nuss, P., & Blengini, G. A. (2018). Measuring progress towards a circular economy: A monitoring framework for economy-wide material loop closing in the EU28. *Journal of Industrial Ecology*, *23*(1), 62–76. doi:10.1111/jiec.12809
[4] Haas, W., Krausmann, F., Wiedenhofer, D., Lauk, C., & Mayer, A. (2020). Spaceship earth's odyssey to a circular economy-a century long perspective. *Resources, Conservation and Recycling, 163*, 105076.
[5] Haas, W., Krausmann, F., Wiedenhofer, D., & Heinz, M. (2015). How circular is the global economy?: An assessment of material flows, waste production, and recycling in the European Union and the World in 2005. *Journal of Industrial Ecology, 19*(5), 765–777. doi:10.1111/jiec.12244
[6] Kovanda, J. (2014). Incorporation of recycling flows into economy-wide material flow accounting and analysis: A case study for the Czech Republic. *Resources, Conservation and Recycling*, *92*, 78–84. doi:10.1016/j.resconrec.2014.08.006
[7] Nuss, P., G.A. Blengini, W. Haas, A. Mayer, V. Nita, and D. Pennington. (2017). *Development of a Sankey diagram of material flows in the EU economy based on Eurostat data*. JRC Technical Reports, EUR 28811 EN. Luxembourg: Publications Office of the European Union. Retrieved from: JRC website

Table one *gives an overview of the system of indicators for monitoring economy-wide loop closing.*

DIMENSION	INPUT-SIDE		OUTPUT-SIDE	
	SCALE (TONNES)	RATE (%)	SCALE (TONNES)	RATE (%)
Circular material flows	**Secondary Materials:** Materials that have been previously used and have been recovered or prepared for reuse[8]	**Circularity Metric (Input Technical Cycling rate (ITCr)):** The share of secondary materials including technical biomass[9]—both recycled and downcycled—in total processed materials[10]	Waste destined for recycling[11]	**Output Technical Cycling rate (OTCr):** The share of secondary materials—both recycled and downcycled—in total processed output, which includes all solid, liquid and gaseous waste[12]
	Carbon-Neutral Biomass: The share of primary biomass consumed (excluding technical biomass) of which carbon content remains sequestered in the soil	**Input Ecological Cycling Potential rate (IECPr):** The share of Carbon-Neutral Biomass in total processed materials	Waste and emissions from Carbon-Neutral Biomass (excluding 'technical' biomass)	**Output Ecological Cycling Potential rate (OECPr):** The share of waste and emissions from Carbon-Neutral Biomass in total processed output
Linear material flows	**Non-Carbon-Neutral Biomass:** The share of primary biomass consumed (excluding technical biomass) of which carbon content is lost to the atmosphere	**Input Non-Renewable Biomass rate (INRBr):** The share of Non Carbon-Neutral Biomass in total processed materials	Waste and emissions from Non-Carbon-Neutral Biomass (excluding technical' biomass)	**Output Non-Renewable Biomass rate (ONRBr):** The share of waste and emissions from Non-Carbon-Neutral Biomass in total processed output
	Other Virgin, Non-Renewable Materials: Finite materials and technical' biomass extracted from the environment and destined for disposal without recovery[13]	**Input Non-Renewable Flows rate (INRr):** The share of other Virgin, Non-Renewable Materials in total processed materials	Waste disposed of without recovery: Includes waste from both short-lived applications and stocks	**Output Non-Renewable Flows rate (ONRr):** The share of other Virgin, Non-Renewable Materials in total processed output
	Fossil Fuels used for energy purposes	**Input Non-Circular Flows rate (INCr):** The share of Fossil Fuels used for energy purposes in total processed materials	Emissions and waste from Fossil Fuels used for energy purposes	**Output Non-Circular Flows rate (ONCr):** The share of Fossil Fuels used for energy purposes in total processed output
Stock build-up	**Net Additions to Stock (NAS):** The amount of virgin materials, including technical biomass being added to long-term	**Net Stocking (NSr):** The share of NAS in total processed materials	n.a.	n.a.

[8] Although currently accounting only for materials recovered from recycling (secondary raw materials) and by-products, this category also includes materials in products that have been reused, refurbished, or repaired as well as components that have been remanufactured.
[9] 'Technical biomass' refers to processed materials of biological origin that are difficult to reintroduce into the biosphere safely. These can be biological materials in short-lived applications such as paper, wood packaging, textiles, and bioplastic or long-term applications such as timber used for buildings.
[10] Processed materials include all primary and secondary material consumed within a defined geographical scope.
[11] Due to data limitations, it is assumed that waste destined for recycling is a good proxy for secondary materials that will be deployed in the economy within the accounting year, according to Eurostat. In reality, there are time lags and inefficiencies in the waste management system: this means that the amount of waste available for recycling and the secondary materials flowing into the economy in the same year are not necessarily the same.
[12] Processed output is a synonym for interim output (intout), a term often used in *Methodology for Nations*. It excludes oxygen as well as bulk water flows.
[13] Includes materials extracted from the environment in the current (throughputs) and past (demolition and discard) accounting years that will become waste in the current accounting year.

	material reserves at the net of their depletions			

For more information on the individual indicators, refer to *Methodology for Nations* (Section 4.1), with the following notes:

- Some names and definitions may differ between the methodology documents for Nations, Latin America and the Caribbean, and this document. For instance, in this document the term renewable biomass' has been replaced with 'Carbon-Neutral Biomass.' In some cases, this is purely a change in terminology with no difference in meaning. In others, the change in name reflects a change in meaning.

- The methodology documents for Nations and Latin America and the Caribbean distinguish between direct and life-cycle indicators, which are calculated based on either Domestic Material Consumption (DMC) or Raw Material Consumption (RMC) flows. While this distinction is important for regional and national analyses, it is not relevant at the global level, where there is no difference between DMC and RMC. For this reason, the distinction is not made in this document. However, it is important to note that the differentiation between direct (DMC-based) and life-cycle (RMC-based) indicators remains relevant in the broader *CGR Measurement Framework* and CIS, as the framework is structured at the national level and global figures are derived from the aggregation of national results.

- Updates were made to the calculation of the IECPr indicator:
    - The biomass fraction allocated to Gross Additions to Stocks (GAS) was excluded from the IECPr. This change prevents double counting between IECPr and NSr, and enables more precise monitoring of biomass entering the technical cycle;
    - Land Use, Land Use Change, and Forestry (LULUCF) emissions were replaced with emissions from deforestation in calculations related to the carbon-neutral share of biomass in the ECPr and NRBr indicators, on both the input and output sides. This adjustment was made to avoid distorted inclusion of 'credits,' particularly those linked to negative LULUCF emissions embodied in traded biomass products.

With the increasing number of frameworks and emerging standards for measuring circularity, the issue of alignment and compatibility becomes relevant. To address this, the CIS was evaluated against two of the existing works on measuring circularity, namely:

- The *Conference of European Statisticians Guidelines for Measuring Circular Economy, Part A: Conceptual Framework, Indicators and Measurement Framework* prepared jointly by the United Nations Economic Commission for Europe (UNECE) and Organisation for Economic Co-operation and Development (OECD);

- The *ISO/DIS 59020:2023(E) Circular economy—Measuring and assessing circularity* standard, by the International Organization for Standardization (ISO).

Areas for improvement and alignment were identified and new features developed, including an expanded tiered structure to increase the interpretability and operationalisation of the CIS. Table two summarises key relationships between the CIS and the other two frameworks and illustrates the new tiered structure with the underlying sub-indicators. For more information and a comparative analysis of the three frameworks, refer to the white paper accompanying the *CGR 2025*: *A Common Framework to Monitor and Measure Circularity*.

Table two *lists the CIS structure and its relationship with key elements of the* CES Guidelines for Measuring Circular Economy, Part A: Conceptual Framework, Indicators and Measurement Framework *(theme, topics, tiered structure) and the* ISO/DIS 59020 standard *(category, content, principle).*

CES guidelines	**Themes**	**1) Material life cycle, value chain → production and consumption 2) Interactions with the environment → environmental effectiveness**										
	Topics	1.1) Material basis of the economy: Production, consumption and accumulation 1.3) Interactions with trade										
		1.2.1) Circularity of material flows						1.2.2) Management efficiency of materials & waste				
		2.1) Natural resource implications						2.2) Environmental quality implications				
ISO standard	**Category**	Resource Inflows (I)					Accumulation	Resource Outflows (O)				
	Content	Recycled & Reused	Virgin Renewable	Virgin Non-Renewable**			Accumulation	Recycling & Reuse	Recirculation	Non-Recovered**		
	Principle	∑ = 100%						∑ = 100%				
CIS	**Headline indicators (Tier 1)**	Circularity (Circular material flows)		Circularity Gap (Linear material flows)			Circularity Lag (Stock build-up)	Circularity		Circularity Gap (Linearity)		
		(I)TCr	(I)ECPr	(I)NRBr	(I)NCr	(I)NRr	NSr	(O)TCr	(O)ECPr	(O)NRBr	(O)NCr	(O)NRr
	Complementary indicators [14,15,16] **Tier 2)**	**- DMC/I (tonnes)** **- RMC/I (tonnes)** - Secondary material consumption/I (tonnes)[17] **- Circular Material Use Rate (CMUR)**	- DMC biomass (tonnes) - RMC biomass (tonnes) - Reclamation rate of organic substances - Share of forested land - Land protection rate - Water protection rate[18] **- Water stress level**		- Total primary energy supply (EJ) - Share of electricity in final energy consumption - Share of renewable energy in final energy	- Self-sufficiency by raw material[21] - Material import dependenc	- NAS (tonnes) - Renewable biomass as a share of NAS - Growth rate of built-up area - Average lifetimes of asset	**- Recycling rate** - Waste collection rate - Waste as share of DPO	- LULUCF emissions[26] (tonnes) **- Safely treated wastewater flows**		**- GHG emissions[27] (tonnes)** - Emissions to air as share of DPO - Average	**- Total waste generation (tonnes)** **- Controlled/uncontrolled disposal rate**

[14] Units are in % unless otherwise specified.
[15] Working list. Where possible and applicable—trends, mix and intensities—are included as per CES guidelines recommendations.
[17] Domestic use plus imports minus exports of waste destined to recycling, by-products and reused products.
[21] Not reported in the *CGR 2025* report because this is only relevant at the national level.
[26] Territorial and consumption-based perspectives.
[27] Territorial, production- and consumption-based perspectives.

			- Ecological overshoot[19]	consumption - Energy efficiency of asset categories[20] (various) - Fossil fuel subsidies (€)	y[22]	categories (years)[23] - Average 'R' rates of asset categories[24]	- Footprint index[25]		emission intensities of asset categories[28]	
	Contextual indicators[29] (Tier 3)-									

* Blue = Technical Cycle, Green = Ecological Cycle

** Includes both potentially circular and inherently non-circular materials that are non-renewable and non-recoverable

[16] Corresponds to core and complementary CES guidelines indicators. Indicators marked in **bold** correspond to the CES guidelines' **core indicators (or proxies thereof)**.
[18] Not reported in the *CGR 2025*.
[19] Placeholder for core indicator 'Natural resource index/depletion ratios'. Not reported in the *CGR 2025*.
[20] Depending on the asset type, energy efficiency can be measured in different ways, for example: primary energy demand in buildings (MJ/km2), fuel efficiency in vehicles (lt/km) or energy efficiency in appliances (% or energy labels). Not reported in the *CGR 2025* due to lack of comprehensive data.
[22] Not reported in the *CGR 2025* report because this is only relevant at the national level.
[23] Placeholder for SO/DIS 59020:2023(E) 'lifetime ratio' indicator.
[24] 'R' rates refers to the different types of strategies for loop closing such as renovation, refurbishment, or remanufacturing which apply to different asset types such as buildings, appliances and equipment, or vehicles. Not reported in the *CGR 2025* due to lack of comprehensive data.
[25] Production- and consumption- based, according to Eurostat's approach for the cei_gsr010 indicator. Not included in the *CGR 2025* due to scope limitation.
[28] Depending on the asset type, emissions can be measured in different ways (for example, kgCO2/MJ, kgCO2/lt). Not included in the *CGR 2025* due to scope limitation.
[29] Contextual indicators were not explicitly reported in the *CGR 25.* However, they remain part of the framework.

3. CGR MEASUREMENT FRAMEWORK

Grounded in the Common Framework of the System of Environmental-Economic Accounts (SEEA-CF) and its EW-MFA subsystem, the *CGR Measurement Framework* builds upon leading academic work in the field of industrial ecology by extending the scope of traditional EW-MFA and providing a more comprehensive measure of the scale and circularity of total material and waste flows and their technical and ecological loop closing. For a more detailed description of the differences between the traditional and extended EW-MFA approach refer to the Economy-Wide Material Flow Accounting section in Annex A of the *Methodology for Nations*.

Consistent with the SEEA-CF, the *CGR Measurement Framework's* conceptual foundation sees the socioeconomic system as being inside the environment, with flows between and within the two. While the scope of this analysis is global, the framework is set up at the national level to capture trade implications: that is, flows between a domestic economy and environment and other economies and the non-domestic environment. This is an important layer to be considered, for example, when calculating footprints and related indicators at the national level. The *CGR Measurement Framework* introduces several key distinctions that enhance its analytical capabilities:

- **Distinction between rate and scale indicators**: Rate indicators at the input side measure the share of secondary (denoted with light blue in Figure one) and ecologically cycled (light green) materials in processed materials (defined as primary and secondary material inputs), and at the output side the share of technically (light blue) and ecologically (light green) cycled materials in interim outputs (defined as all waste and emissions before recovery and recycling or discharge to the environment). The rate indicators measure the circularity performance—from 0% in a linear economy with neither technical nor ecological cycling—to 100% in a (thermodynamically unfeasible) perfect circular economy, where all processed materials are cycled without losses in loops;

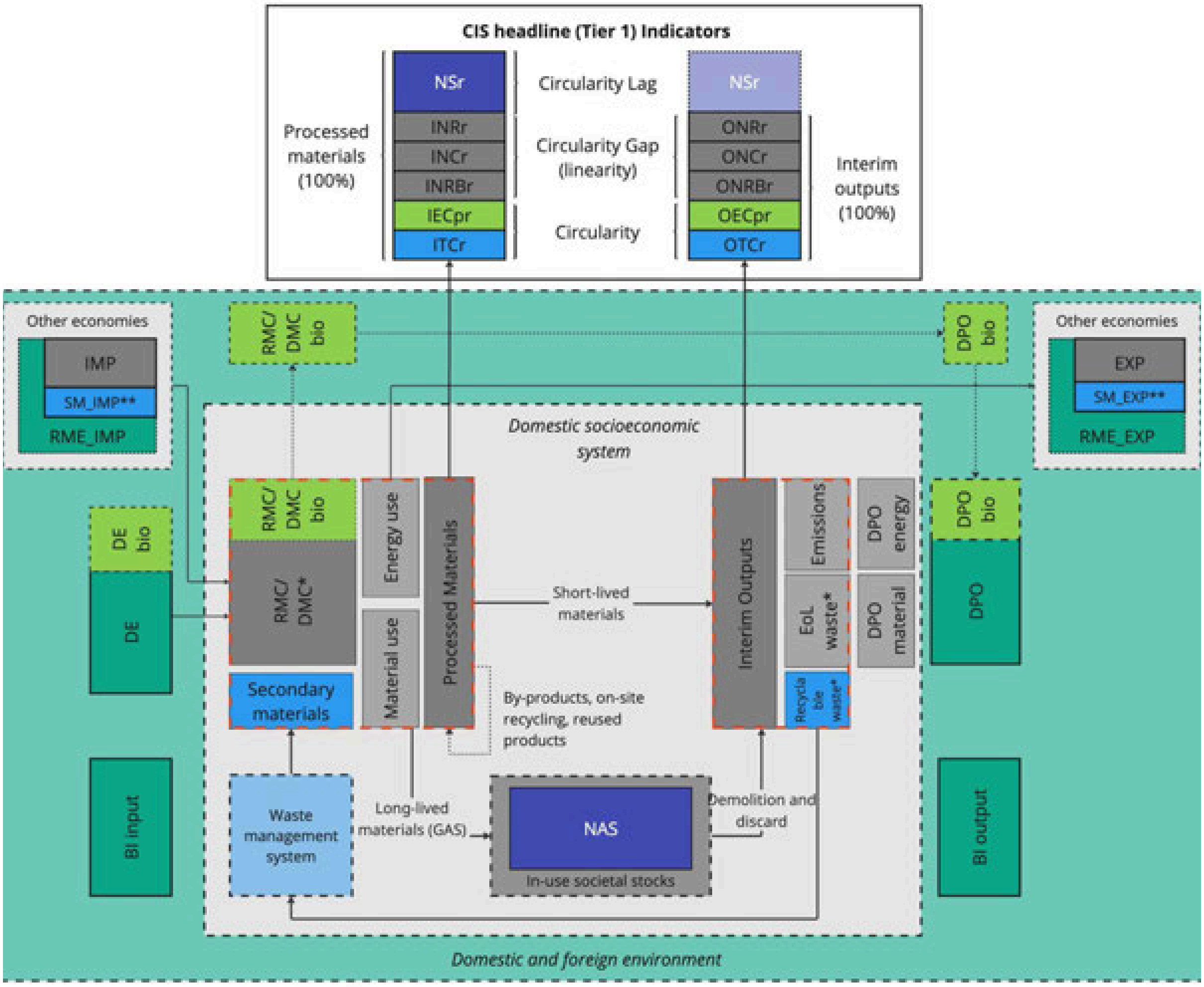
- **Distinction between technical and ecological cycling rates:** Both rates are derived from the same underlying system definition and relate the respective cycled flows to the same reference flow (i.e., to processed materials on the input side and processed outputs on the output side). They are, therefore, consistent, additive, mutually exclusive and applicable across scales. Technical cycling refers to the flow of re- and down-cyclable end-of-life waste (output side) handled by waste management and reintroduced into the market in the form of secondary materials (input side). It also includes by-products that are reused before becoming waste. Ecological cycling refers to the flow of renewable biomass—or in our case carbon-neutral biomass—and the resulting outflows to the environment, which re-enter global biogeochemical cycles. Indicators related to these flows are shown in light green in Figure one;

- **Distinction between natural and anthropogenic flows:** Natural flows are resources (such as raw materials extracted on the input side) or residuals (such as emissions and waste discharged on the output side) that originate from or are destined to the environment. It is important to note the difference between natural (dark green in Figure one) and biological (light green) flows. Natural flows can comprise both biological and potentially renewable materials (light green) and inert non-renewable ones. On the other hand, anthropogenic flows (grey and light blue) are of mixed composition that originate from or are destined to other socioeconomic systems. While natural flows contain only resources, anthropogenic flows can also contain man-made artefacts such as manufactured and semi-manufactured products. This distinction is particularly relevant in the context of trade and the calculation of upstream requirements (or raw material equivalents) in material footprinting;

- **Distinction between flows and socioeconomic stocks:** Activities of the socioeconomic system are fed by flows of materials from the natural environment, which are then processed by industries, and are either accumulated in physical stocks (additions to the stock of fixed assets) or transformed and released back to the natural environment as residuals. Materials stockpiled in buildings, infrastructure, and durable goods in the economy (long-term materials), as well as old materials that are removed from stock as buildings are demolished and durable goods disposed of (demolition and discard), are captured by the NAS indicator (dark blue). NAS measures the physical growth of the economy and exposes the time lag between material consumption and waste generation, which is key to addressing circularity through strategies aimed at extending product lifetimes such as renovation, repair, refurbishment, remanufacturing, and sharing. In our framework, these strategies would result in an increase of the service lifetime of in-use stocks and potentially a stabilisation of in-use stock growth, as indicated by NAS. Thus, even though we don’t have data on the prevalence of these strategies, their effects can be observed through this indicator, especially in combination with supporting lower-tier indicators.

Figure one shows the structure of the *CGR Measurement Framework* and its link with the CIS headline indicators. The colour coding highlights the relationship between some variables of the framework, the CIS indicators and the key distinctions mentioned above.

***Figure one** pictures a simplified extended EW-MFA framework based on Mayer et al. (2018). This framework applies to individual materials (for example, domestic extraction of corn or iron) to aggregated material categories (for example, processed materials (PM) of biomass, fossil energy carriers) to the total material level (for example, total domestic extraction).*



Notes: Full lines/boxes = 'direct' material flows/indicators; Dotted lines/boxes = 'embodied' material flows/indicators; Dashed lines/boxes = system boundaries; I = Input; O = Output; TC = Technical Cycling (materials cycled within the socioeconomic system); EC = Ecological Cycling (material cycled within the environmental system); NR = Non-Renewable (potentially circular inert materials, such as metals and minerals), NRB = Non-Renewable Biomass (non-carbon neutral biomass); NC = Non-Circular (materials that are inherently non-circular, such as fossil fuels); NS = Net Stocking; DE = Domestic Extraction; IMP = Imports; EXP = Exports; RME = Raw Material Equivalents; SM = Secondary Materials; R/DMC = Raw/Domestic Material Consumption; DPO = Domestic Processed Output; NAS = Net Additions to Stocks; BI = Balancing Items.

*DMC/RMC exclude flows of Unused Domestic Extraction, EoL waste includes streams from Unused Domestic Extraction
**For simplicity, SMimp and SMexp are assumed to include waste for recycling (RCV_R), by-products (BP) and reused products (RP).

Table three shows the additional variables that are calculated/available through using the extended MFA approach versus the traditional approach. While figures from the extended approach are those that are published, results from the traditional approach are still extremely important for benchmarking, sanity checking and reconciliation (see Section five) purposes. Note:

greyed out cells means that the variable is not included in the approach, empty cells means that the variable is input data with no calculation needed.

Table three *summarises traditional and extended MFA variables with descriptions and formulas.*

LABEL	CODE	DESCRIPTION	TRADITIONAL	EXTENDED
Domestic extraction	DE	Extraction of raw materials from the domestic environment		
Physical imports	IMP	Imports of raw materials, semi-finished and finished products		
Raw material equivalents of imports	RME_IMP	Indirect flows or upstream raw material requirements related to imports		
Physical exports	EXP	Exports of raw materials, semi-manufactured and manufactured products		
Raw material equivalents of exports	RME_EXP	Indirect flows or upstream raw material requirements related to exports		
Domestic material input	DMI	Primary material inputs into an economy	$DE + IMP$	$DE + IMP$
Raw material input	RMI	Primary inputs into an economy expressed in raw material equivalents	$DE + RME\_IMP$	$DE + RME\_IMP$
Domestic material consumption	DMC	Primary material or apparent consumption of an economy	$DMI - EXP$	$DMI - EXP$
Raw material consumption	RMC	Primary consumption of an economy expressed in raw material equivalents	$RMI - RME\_EXP$	$RMI - RME\_EXP$
Recycled waste for domestic consumption	$RCV\_R\_B_{cons}$	Domestic (excluding exports) and imported waste recycled in domestic recovery plants. Does not include waste from unused extraction. Recycling includes backfilling.		$RCV\_R\_B_{dom} + RCV\_R\_B_{imp} - RCV\_R\_B_{exp}$
By-products for domestic consumption	BP_{cons}	Domestic (excluding exports) and imported by-products for domestic consumption		$BP_{dom} + BP_{imp} - BP_{exp}$
Reused products for domestic consumption	RP_{cons}	Domestic (excluding exports) and imported reused products for domestic consumption		$RP_{dom} + RP_{imp} - RP_{exp}$
Secondary material inputs consumed	$SMIc$	Secondary material consumption of an economy		$RCV\_R\_B_{cons} + BP_{cons} + RP_{cons}$
Processed materials	PM	Primary and secondary material consumption of an economy		$DMC + SMIc$
Processed raw materials	PRM	Primary and secondary material consumption of an economy where primary material consumption only is expressed in raw material		$RMC + SMIc$

		equivalents[30]		
Energy use	$eUse$	Fraction of PM that is used to provide energy. Comprises not only technical energy but also feed for livestock and food for humans.		Calculated based on coefficients from material flow databases, Mayer et al. (2018), FAOSTAT food[31] and UNSTAT energy balances[32]
Material use	$mUse$	Fraction of PM that is used for material purposes. Comprises all metals and non metallic minerals, fractions of biomass and fossil energy carriers.		
Gross additions to stock	GAS	Long-lived materials used to build up in-use stocks of materials (lifespan of over one year)		
Reported waste from energetic use	W_eUse	Solid waste from the combustion of fuels and human and livestock excrement at the same water content of biomass intake (i.e. excluding water uptake by humans and livestock) as reported in official statistics		Calculated from waste statistics and Mayer et al. (2018)
Reported waste from material use	W_mUse	Solid waste from discarded stocks (lifespan over one year), short-lived products (lifespan less than one year) and processing and manufacturing waste		
Short-lived material use of crop residues	Crp	Crops residues for feed and deliberative dissipative uses (fertilisers)		Based on Mayer et al. (2018)
Demolition and discard	$D\&D$	Solid waste from discarded in-use stocks. Comprises construction and demolition waste but also all other discarded long-living products		$W\_mUse - (mUse - GAS - - Crp)$
Reported end-of-life waste	EoL_r	Total end-of-life waste comprising all solid waste from $eUse$ and $mUse$, including throughput materials reported in waste statistics		$W\_eUse + W\_mUse$
Unreported waste from energy use	Wu_eUse	Excrement generated from food and feed intake not fully reported in waste statistics		Calculated based on material flow statistics and Mayer et al. (2018)
Extractive waste	Ext	Waste rock from domestic mining	Included but no explicitly quantified	Included but no explicitly quantified
Unreported waste from material use	Wu_mUse	Waste from material uses not fully reported in waste statistics. This can include country-specific under- or mis-reported waste fractions required for mass balancing (Wu)		$Crp + Ext + Wu$
Unreported end-of-life waste	EoL_u	Total waste not reported in waste statistics		$Wu\_eUse + Wu\_mUse$

[30] Methodological issues related to the estimation of secondary materials in raw material equivalents can be found in this Technical Note.
[31] United Nations Statistics Division. (2022). Energy balances. Retrieved from: UN Stats website
[32] FAO. (2025). *Food balance sheets and supply utilization accounts resource handbook 2025*. FAO Statistical Development Series, No. 20. Rome. doi:10.4060/cd4472en

Total end-of-life waste	EoL_t	Total reported and unreported waste		$EoL_r + EoL_u$
Domestic processed output from energy (emissions)	DPO_e	All gaseous outputs including vapour from combustion and human and animal respiration excluding oxygen input from air		$eUse - W\_eUse - Wu\_eUse$
Domestic processed output from materials	DPO_w	All end-of-life waste excluding materials recovered for re- and downcycling. All liquid and solid outputs including moisture content as included in extracted material but excluding extra added water (for example, during industrial processes or drinking water)		$EoL_t - RCV\_R\_B_{dom}$
Domestic processed output	DPO	Total waste and emissions released to the environment		$DPO_e + DPO_w$
Interim outputs	$IntOut$	Total waste and emissions after the use phase		$EoL_t + DPO_e$
Balancing items input-side	BI_{in}	Mostly oxygen demand for combustion and respiration processes		All variables are pre-calculated at the net of the balancing items
Balancing items output-side	BI_{out}	Mostly water vapour generated from combustion processes, gases from respiration and evaporated water from biomass products		
Net additions to stock	NAS	Measure of the physical growth of the economy, i.e. the quantity (weight) of new construction materials accumulating in buildings, infrastructure and materials incorporated in durable goods (lifespan over one year)	$DMC + BI_{in} - BI_{out} - DPO$	$GAS - D\&D$
Emissions from deforestation	Def	Technically not part of the EW-MFA framework as this is an environment-to-environment flow. Included in the extended approach for calculations related to the biological cycle		Based on Singh et al. (2024)[33]

For an extensive description of the *CGR Measurement Framework*, refer to the Annex A in *Methodology for Nations*. Note that due to limitations related to data and practical implementation, an integral application of the *Methodology for Nations* was not possible for the global context of the *CGR 2025*. These differences are formulated as methodological limitations and are listed in Section five.

[33] Singh, C., Persson, U. M., Croft, S., Kastner, T., & West, C. D. (2024). Commodity-driven deforestation, associated carbon emissions and trade 2001-2022 (2.0) [Data set]. Zenodo. doi:10.5281/zenodo.10633818

4. MODULES

The implementation of the *CGR Measurement Framework* is divided into four modules and operationalised through a proprietary python package called the *CGR Engine.*[34] Table four summarises the structure of the *CGR Engine* and the correspondence between the python modules and the EW-MFA modules as presented in the IRP's *Global Manual on EW-MFA.*[35]

***Table four** outlines correspondence between the python modules and the EW-MFA modules as presented in the IRP's* Global Manual on EW-MFA*.*

<table>
<tr><th>EW-MFA MANUAL</th><th colspan="2">CGR ENGINE</th><th>NOTES</th></tr>
<tr><td>Module one: Domestic material extraction (DE), direct physical imports (IMP) and exports (EXP)</td><td colspan="2" rowspan="2">Module 1: Materials</td><td rowspan="2">RME_IMP, RME_EXP and RMC are imported in the engine from CE's Weavebase model[36] (see section Environmentally Extended Multi-Regional Input-Output Analysis—Weavebase model in Annex A of the Methodology for Nations document)</td></tr>
<tr><td>Module two: Raw material equivalents of trade (RME_IMP, RME_EXP) and material footprint (RMC)</td></tr>
<tr><td rowspan="4">Module three: Material outflows</td><td colspan="2">Module 2: Emissions</td><td>Emission data is imported from Circle Economy's Weavebase model</td></tr>
<tr><td rowspan="3">Module 3: Waste</td><td>Module 3.1:Waste generation and treatment</td><td>Waste generation and treatment draws from a variety of databases and estimation methods</td></tr>
<tr><td>Module 3.2: Waste trade</td><td>Trade in waste and secondary materials is estimated from international bilateral trade data</td></tr>
<tr><td>Module 3.3: Other outputs</td><td>Other outputs module includes non-exhaustive estimations of dissipative uses emissions to water and dissipative losses are currently not included)</td></tr>
<tr><td>Module four: Material balance and stock accounts</td><td colspan="2">Module 4: Balancing items and stock additions</td><td>For the traditional EW-MFA approach, balancing items and NAS are calculated according to the IRP's and Eurostat's approaches

For the extended EW-MFA approach, balancing items are intrinsically included and NAS is calculated through a number of variables pulled from all the other modules</td></tr>
<tr><td>Module five: Unused extraction</td><td colspan="2">-</td><td>Currently, there is no module dedicated to unused extraction. Flows related to this are typically excluded in datasets related to Module one, but included in those related to Module three due to different systems boundaries in data collection. This creates an 'harmonisation issue' between datasets (see Section five)</td></tr>
<tr><td>Module six: Material flow accounts by industry</td><td colspan="2">-</td><td>Currently, this is out of the scope of the CGR Measurement Framework.</td></tr>
</table>

[34] Circle Economy (2025). CGR Engine - technical documentation. Retrieved from: Circle Economy website
[35] UNEP (2021). The use of natural resources in the economy: A Global Manual on Economy Wide Material Flow Accounting. Nairobi, Kenya
[36] Circle Economy (2025). Weavebase - technical documentation. Retrieved from: Circle Economy website

In reference to the above, Table five gives a summary of main data sources per module and per indicator. In Table five, the 'Emissions module' and 'Other outputs submodule' are not included because the related flows are estimated through mass balancing in the extended approach computations. Nevertheless, these modules are a key part of the *CGR Engine* computations related to the traditional approach.

Table five *summarises the main data and sources used in Circle Economy's model for the extended EW-MFA approach classified through RAG (red, amber, green) status.*

	Reliable data that is up-to-date: Annually updated territorial data
	Potential inaccuracies: Scaled, interpolated, nowcasted or otherwise estimated data
	Likely inaccuracies: All other data (such as proxies)

Module (*CGR Engine*)	Label	Code	Source	RAG status
Module 1: Materials	Domestic extraction	DE	UNEP IRP Global Material Flows Database, Trade Common Compilation Categories (TCCC) research bundle August 2024, Eurostat env_ac_mfa[37]	
	Physical imports	IMP		
	Physical exports	EXP		
	Raw material equivalents of imports	RME_IMP	D_imp extracted from Weavebase database	
	Raw material equivalents of exports	RME_EXP	D_exp extracted from Weavebase database	
Module 3.2: Waste trade	Imported secondary materials	SM_{imp}	$RCV\_R\_B_{imp}$: Estimated from BACI: International Trade Database at the Product-Level[38] BP_{imp}: Estimated from BACI: International Trade Database at the Product-Level RP_{imp}: Not included	
	Exported secondary materials	SM_{exp}	$RCV\_R\_B_{exp}$: Estimated from BACI: International Trade Database at the Product-Level BP_{exp}: Estimated from BACI: International Trade Database at the Product-Level RP_{exp}: Not included	
Module 3.1: Waste generation and treatment	Waste recycled (domestic secondary materials)	SM_{dom}	$RCV\_R\_B_{dom}$: Estimated from the What-a-Waste (WaW) database,[39] Eurostat env_wastrt,[40] the OECD and various sources for country-specific bottom-up corrections BP_{dom}: Not included	

[37] Eurostat. (2024). Material flow accounts (env_ac_mfa). Retrieved from: Eurostat website
[38] Gaulier, G. & Zignago, S. (2010). BACI: International trade database at the product-level. The 1994-2007 version. CEPII Working Paper, N°2010-23. Retrieved from: CEPII website
[39] World Bank. (2018). What a waste 2.0: Global database. Retrieved from: World Bank website
[40] Eurostat. (2024). Treatment of waste by waste category, hazardousness and waste management operations (Data code: env_wastrt). Retrieved from: Eurostat website

			RP_{dom}: Not included	
Module four: Balancing items and stock additions	Energy use	$eUse$	Calculated based on TCCC research bundle data, UNSTAT energy balances,[41] and FAOSTAT food balances[42] based on Mayer et al. (2018)	
	Material use	$mUse$		
	Gross additions to stock	GAS		
	Reported waste from material use	W_mUse	All waste recorded in the *CGR* dataset (excl. was_{unacc})	
	Short-lived material use of crop residues	Crp	Estimated based on Mayer et al. (2018)	
	Extractive waste	Ext	Included but not explicitly estimated	
	Unreported waste from energy use	Wu_eUse	Calculated based on the TCCC research bundle data, Mayer et al. (2018) and FAOSTAT livestock data[43]	
	Unreported waste from material use	Wu_mUse	Estimated based on mass balance	
-	Reported waste from energy use	W_eUse	Not recorded as excluded from the *CGR* dataset by design	

4.1 Module one: Materials

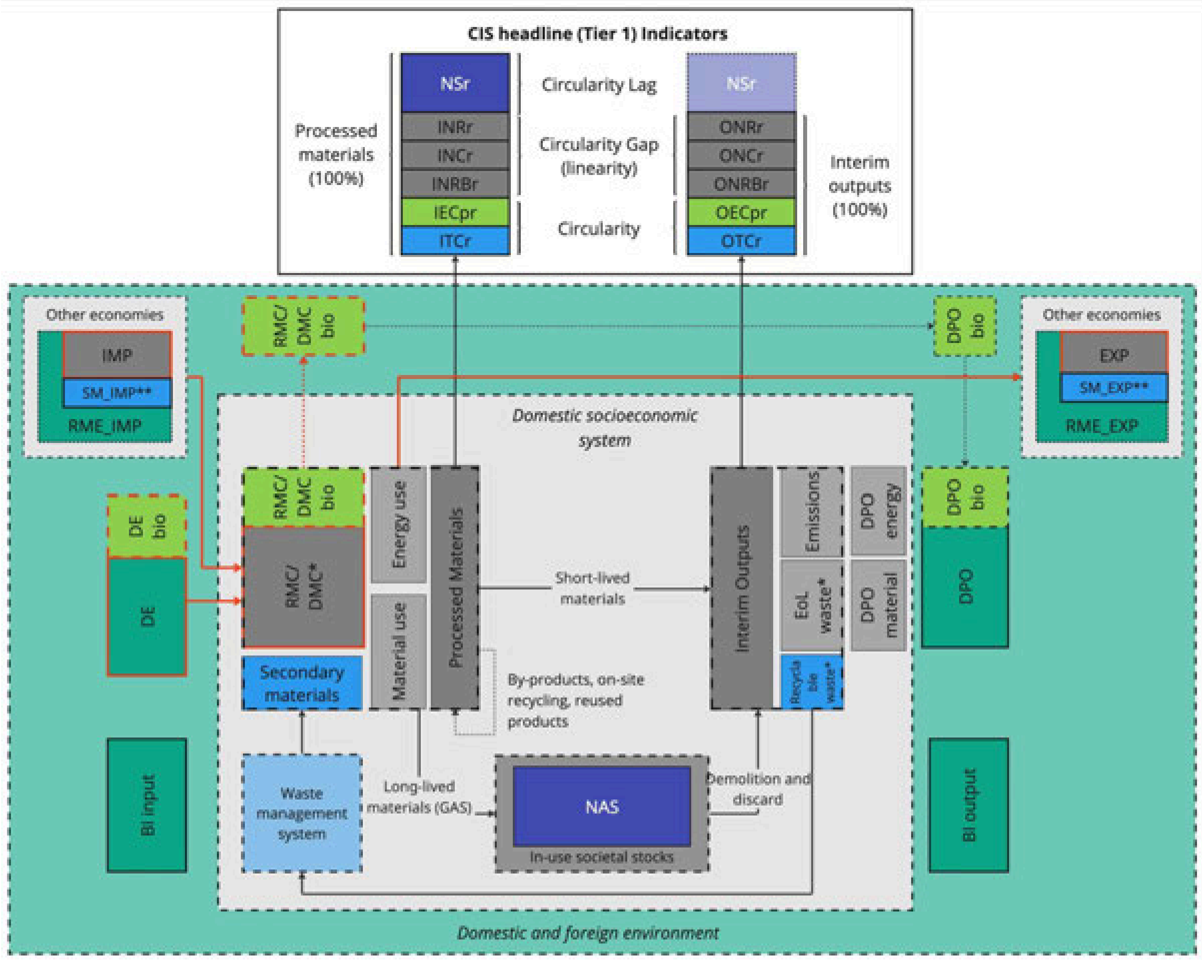
4.1.1 Description

This module forms the core of a national or regional material flow data set. Figure two highlights the components of this module in red.

It includes the DE of materials that are further used in economic processes, usually accounted for at the point when the natural resource becomes commoditized and a price is attached. The aggregate flow DE covers the annual amount of solid, liquid and gaseous raw materials (except for water and air) extracted from the natural environment to be used as material factor inputs in economic processing. The term 'used' refers to the acquisition of value within the economic system and is a very relevant criteria in the definition of system boundaries on the input as much as on the output side.

[41] United Nations Statistics Division. (2022). Energy balances. Retrieved from: [UN Stats website]
[42] FAO. (2025). *Food balance sheets and supply utilization accounts resource handbook 2025*. FAO Statistical Development Series, No. 20. Rome. doi:10.4060/cd4472en
[43] FAO. (2024). FAOSTAT: Crops and livestock products. FAOSTAT. [Accessed on 24/11/2022]. Retrieved from: [FAO website]

__Figure two__ pictures a simplified extended EW-MFA framework based on Mayer et al. (2018) with elements of Module one highlighted. Refer to the 'Note' following Figure one for a summary of acronyms used in this visual.



At the reporting level (MF1), DE, IMP and EXP consist of the four main resource groups: biomass, fossil fuels, metal ores and non-metallic minerals. IMP and EXP of goods are measured at the volumes at which they cross national boundaries and typically contain products at different stages of processing, including unprocessed raw materials, semi-manufactured products and finished products. While the aggregation of DE is relatively straightforward, IMP and EXP contain additional product flows that consist mainly of a type of resource ('Products mainly from' [...]), or even mixed and complex products ('Other products'), that do need to be re-assigned to the usual MF1-4 categories to ensure consistent totals. In the context of direct accounts and indicators, these compounded products can be reallocated to different material flows based on their relative shares within the resource group (as per the proportioning principle from Mayer et al. 2018). However, this should not result in negative consumption figures due to an overly negative physical trade balance (PTB). With this data, additional indicators per resource group can be derived including PTB and DMC.

$$PTB = IMP - EXP \text{ and } DMC = DE + PTB$$

Within the *CGR Engine*,the raw material equivalents of trade (RME_IMP, RME_EXP) and the material footprint (RMC) are covered by Module one. These indicators take a final demand perspective of material use by measuring the upstream material requirements to produce direct imports and exports. RMEs assume a similar system boundary (point of extraction and commodification) for domestic and traded materials. The raw material trade balance (RTB) is established by subtracting RME_EXP from RME_IMP. With this information, the material footprint of consumption (MF) or raw material consumption indicator (RMC) is established. The MF attributes global material extraction (wherever it occurs and along the whole lifecycle of natural resources) to final demand in a country where:

$$MF = DE + RME\_IMP - RME\_EXP = DE + RTB$$

For more extensive information on the elements in this module refer to the section Module one: Domestic material extraction (DE), direct physical imports (IM) and exports (EX) of the *CGR Latin America and the Caribbean* methodology document.[44]

4.1.2 Data sources

DE, IMP and EXP are retrieved from the IRP Global Material Flow database, specifically the TCCC bundle and Eurostat's env_ac_mfa datasets for the globe and Europe, respectively. RMC is retrieved from consumption-based accounts (DE stressor in D_cba extension) calculated through the Weavebase model (see section Environmentally Extended Multi-Regional Input-Output Analysis—Weavebase model in Annex A of the *Methodology for Nations* document).

4.1.3 Gaps and limitations

Due to the high detail in the TCCC data bundles, cases of negative DMC for a detailed TCCC code are possible. Although most of them are likely related to data errors, these cases are not corrected because it cannot be guaranteed that the negative value is not related to an actual large stock outflow.[45] There are also cases of mismatches between extracted and exported flows (for example, Other Bituminous Coal as DE, and Other Sub-Bituminous Coal as EXP). These cases level themselves out when summed to the MF1-4 totals, or even total DMC and thus neglected. Reallocation through proportioning is a temporary solution until a better way to assign complex products to resource groups as well as material/energy use and to stocks versus throughputs is developed.

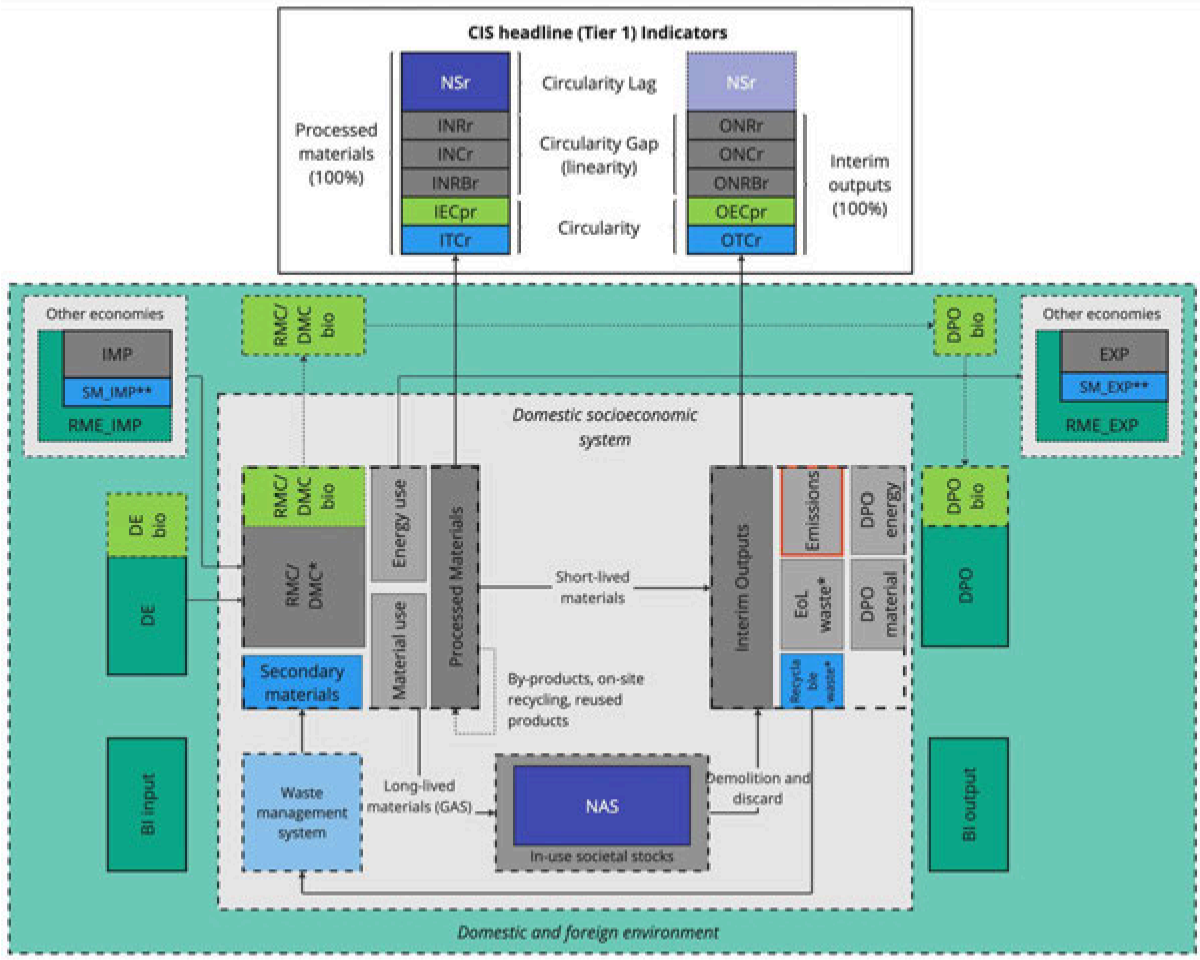
[44] Note that—while the general information presented is valid and the *CGR Latin America and the Caribbean* and global methodologies are highly aligned—country- and project-specific information (such as summary tables) may not be applicable to the *CGR 25*. Any new data sources or approaches specified in this document should be considered as final.
[45] CSIRO. (2024). *Technical annex for global material flows database - 2024 edition*. International Resource Panel. Retrieved from: [IRP website]

4.2 Module two: Emissions

4.2.1 Description

Emissions to air are gaseous or particulate materials released to the atmosphere from production or consumption processes in the economy. Figure three highlights the components of this module in red.

Figure three *illustrates a simplified extended EW-MFA framework based on Mayer et al. (2018) with elements of Module two highlighted.*



In EW-MFA, emissions to air comprise 14 main material categories at the two-digit level including the main GHGs (the so-called 'Kyoto basket'[46]), Long-Range Transboundary Air Pollution (LRTAP) air pollutants[47] and other minor emissions (such as particulate matters, persistent organic pollutants, and heavy metals). Emissions to water include substances and materials released into natural water systems through human activities, after or without passing wastewater treatment (such as materials dumped at sea). For more extensive information on the elements in this module refer to section Module three: Material outflows (Emissions to air (MF.7.1) of the *CGR Latin American and the Caribbean* methodology document.

[46] Statistics Explained. (n.d.). Glossary: Kyoto basket. Retrieved from: Eurostat website
[47] Statistics Explained. (2024). Air pollution statistics - air emissions accounts. Retrieved from: Eurostat website

4.2.2 Data sources

Emission data is retrieved from the production-based accounts (Emissions stressor in D_pba) in Weavebase. Such accounts are built using a combination of the state-of-the-art datasets internationally available (see section Environmentally Extended Multi-Regional Input-Output Analysis—Weavebase model in Annex A of *Methodology for Nations*). A specific extension for emissions from deforestation is added for use in the calculation of the ECPr and NRBr indicators (see Box five: LULUCF versus deforestation in Annex A of *Methodology for Nations*).

4.2.3 Gaps and limitations

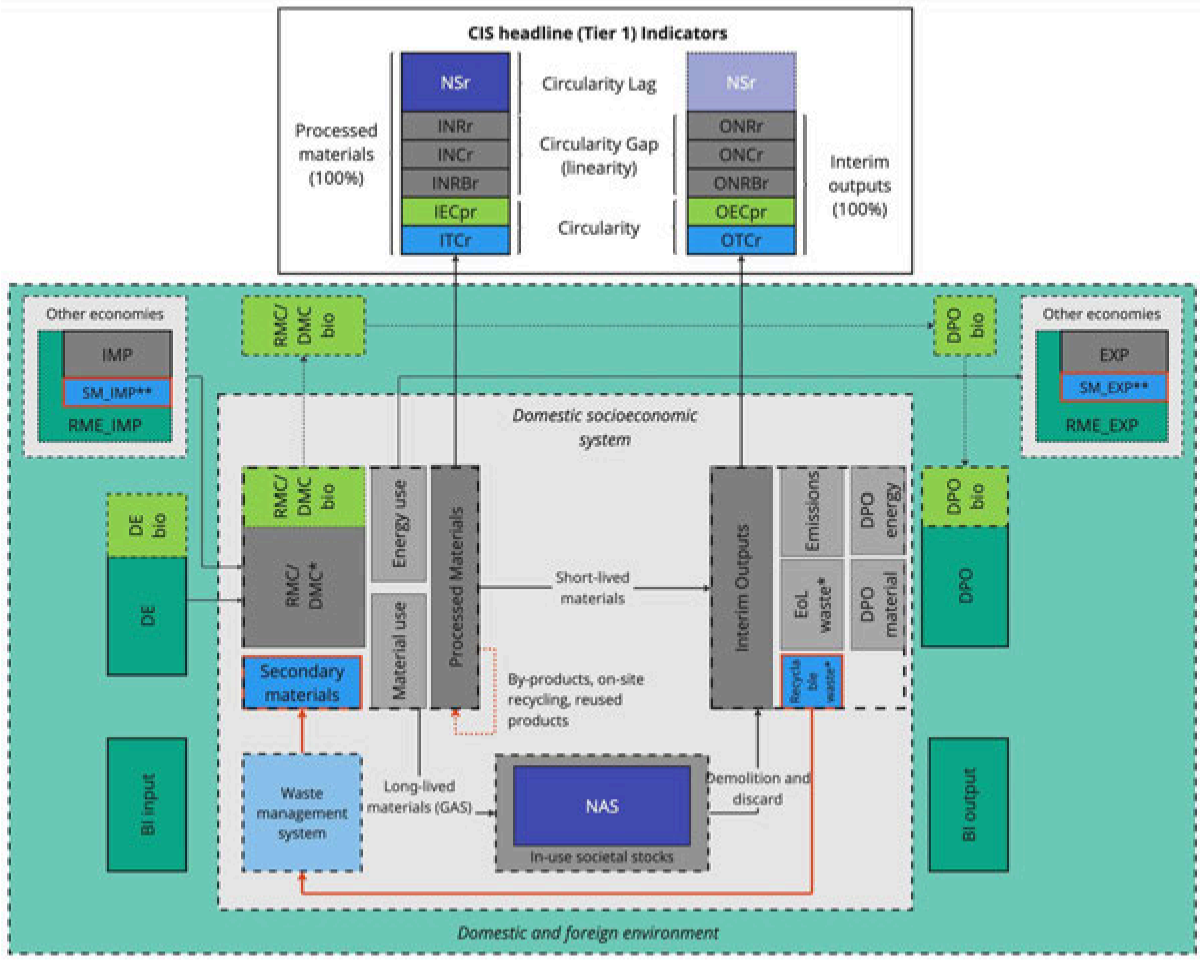
Due to the lack of comprehensive and up-to-date country-level data on minor GHGs and air pollutants, the Weavebase model currently includes only three major ones: carbon dioxide (CO_2) (including from biomass combustion), methane (CH_4) and nitrous oxide (N_2O). Due to the integration of the EDGAR v8.0 database with the Exiobase v3.8.2 and Eora v199.82 extensions, the resulting extension of Weavebase is an incoherent mix inventory (territory principle) and account (resident) emission totals which needs further harmonisation. Accounting for only 1%, emissions to water and dissipative losses represent the smallest category in processed outputs (Matthews et al., 2000) and are therefore not explicitly accounted for within the *CGR Measurement Framework*.

4.3 Module three: Waste

This module consists of three sub-modules:

- Waste generation and treatment
- Waste trade
- Dissipative uses and losses

Figure four *pictures a simplified extended EW-MFA framework based on Mayer et al. (2018) with elements of Module three highlighted.*



4.3.1 Module 3.1: Waste generation and treatment

4.3.1.1 Description

By definition, waste refers to materials that are of no further use to the generator for production, transformation or consumption. Waste may be generated at different stages of the supply chain, from extraction to final use, and from both short-lived material uses (most of municipal solid waste, packaging waste or sludges and ashes from combustion) and long-lived material uses (construction and demolition waste or discarded vehicles, for example).

In the traditional EW-MFA approach, waste is only accounted for to the extent to which it is released back to the environment through open dumping, while landfills are considered as a form of stock addition. Recycled material flows are considered flows within the economy (for example, of metals, paper and glass) and thus are not considered as outputs (nor inputs).

Conversely, in the extended EW-MFA approach, recycled materials (as well as other 'internal flows' such as by-products and reused products) are included while landfills are considered to be part of the environment and not a form of stock addition, and are thus included as part of processed output.

Waste generated from the treatment of waste, also referred to as secondary waste, is not accounted for in the context of this framework as it would translate into double counting.

Waste from unused extraction (such as excavated earth, overburden, dredging spoils, etcetera) and used extraction (such as extractive ore waste, tailings, etcetera) could not be differentiated due to data limitations. In the application of this methodological framework at the national level, input-and output-side statistics are harmonised, as described *Methodology for Nations*. This harmonisation is not possible at the global level.

Recycled flows, hereafter referred to as secondary materials (SM), refer to materials recovered through all forms of recycling including downcycling (for example, backfilling). Reused products and materials including industrial by-products are also considered secondary materials. In this document, the term 'recycled flow' and 'secondary materials' are used interchangeably, as a study carried out by Eurostat[48] concluded that the input to recovery plants is an acceptable proxy for the output from recovery plants. However, it should be noted that there are time lags and inefficiencies in the waste management system: this means that the amount of waste available for recycling and the secondary materials flowing into the economy in the same year are not necessarily the same. The measurement framework was built upon a systems and material perspective of the economy, and based the assessment as far as possible on statistical data from national (i.e. statistical offices) and international (i.e. FAOSTAT, IRP) official environmental reporting systems. While recovered materials were either reported in waste statistics or could be directly quantified, this was not possible for other circular strategies such as the extension of product lifetimes, reuse and remanufacturing, or sharing.

Tracing the transformation of materials from their extraction until their end-of-life requires the integration of EW-MFA and waste statistics. The latter, however, are lacking in many countries and need to be estimated based on available data. One of the most comprehensive databases on waste management is the What-a-Waste (WaW) v2.0 database by the World Bank. This was used as the starting point for the estimation of waste generation, collection and treatment for all countries in the world. While the main advantage of this database is the wide coverage across countries and indicators, the completeness and time coverage of the data points can vary greatly and requires extensive data-gap-filling and extrapolation.

Our step-by-step approach for data manipulation, including interpolation, back- and now-casting is the following:[49]

- **Step one—Primary data collection for bottom-up corrections:** This entailed desk research focused on the largest countries by waste generation (excluding EU countries, see 'Data sources' sections). The database developed for the *CGR Latin America and the*

[48] Eurostat (2018). Circular material use rate: Calculation method. Retrieved from: Eurostat website
[49] Source year refers to the latest year for which reported data was available. Target year refers to the baseline year for which it was decided to estimate the indicator framework based on data availability across all databases employed in the analysis. The target year for the *CGR Latin America and the Caribbean* is 2018.

Caribbean[50] was also included. The data collected covered municipal solid waste (MSW) and special waste (SW) generation, collection rates and treatment rates at the highest level of detail and for the most recent year available;

- **Step two—MSW generation nowcasting:** This analysis assumes that MSW generation grows primarily based on population and affluence. Following the approach used by Kaza et al. (2018),[51] a regression formula based on GDP per capita was used to estimate the development of MSW generation per capita for each country between the source and target years. Population figures from the UN's World Population Prospects[52] were then used to estimate total MSW generation for the target year. If MSW data were available for the target year, the original data was used;

- **Step three—SW and collection rates data interpolation:** Because a lot of the regions have missing data for at least one of the SW subtotals, interpolation was required. While the earlier approach would interpolate within income groups, such a hard cut-off was not always desirable while also reducing the bin size for low-income regions to a very small set of candidates. In the improved interpolation approach, spatial distance and difference (distance) in GDP per capita were used instead. For EU countries, data gaps in Eurostat's time series were filled using basic linear interpolation. For edge data, the first or last known value was used instead. Agricultural waste, entirely made of biomass, is considered as part of the ecological cycle as it is mainly returned back to the environment through soil application or burnt in open fires (emissions from biomass combustion). Because biomass flows on both the input and output side are accounted for by the ECPr indicators rather then TCr ones, agricultural waste was excluded from the SW dataset to avoid double counting;

- **Step four—SW generation nowcasting:** This analysis assumes that SW generation grows primarily based on sectoral gross output. Construction and manufacturing industry output from the Eora database were matched to the corresponding physical waste stream, in this case construction and demolition waste (C&DW) and industrial waste, to calculate SW generation intensities for the source years (various) and multiplied by the historical gross sectoral output for the target year. If waste data was missing, the intensity factor is interpolated using the spatial/income interpolation method described above;

- **Step five—Treatment rates nowcasting**: For each country, treatment rates for a source year were gathered. Time series of gross output for waste treatment sectors were

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[50] Circle Economy. (2023). *The circularity gap report Latin America and the Caribbean: Methodology document (v 1.0)*. Amsterdam: Circle Economy. Retrieved from: [CGRi website]

[51] Kaza, Silpa; Yao, Lisa C.; Bhada-Tata, Perinaz; Van Woerden, Frank. 2018. *What a Waste 2.0: A global snapshot of solid waste management to 2050.* Urban Development. World Bank. Retrieved from: [World Bank website]

[52] UN World Population Prospect 2019 extracted from File POP/1-1: Total population (both sexes combined) by region, subregion and country, annually for 1950–2100 (unit: thousands of people).

gathered from the Input-Output database Exiobase v3.8.2.[53] Based on the source year for which mass-based waste treatment rates were available, (monetary-based) scaling factors were calculated as the ratio between gross output of the waste treatment sectors in the source and target year. Matching tables of WaW treatment types and countries to Exiobase waste treatment sectors and regions were developed, and the monetary-based scaling factors were used to scale the mass-based waste treatment rates. For instance, if the aggregated gross output of all re-processing sectors of a country in Exiobase increased by 10% between the source and target year (i.e. a scaling factor of 1.1), then the recycling rate also increased by 10%. After applying the nowcasting factor, the waste treatment rates were renormalised to sum to 100%. Waste treatment types that do not have a relevant waste sector proxy were ignored (for example,uncontrolled waste disposal). Note that this approach assumes full linearity between the monetary gross output of a waste treatment sector and the physical volume treated by the same. This assumption was not empirically tested. Furthermore, for many non-OECD countries with lacking data, treatment rates for MSW were applied to SW fractions under the assumptions that the two types of waste were treated alike. Finally, within the context of this framework, rates for anaerobic digestion and composting were not included since organic waste flows (such as agricultural waste, food waste, etcetera) are accounted for by the input and output ECPr rather than the input and output TCr;

- **Step six—Top-down consolidation:** Results from the *CGR Engine* were benchmarked against those from the MISO v.1 model. Datasets from two publications using the same input data are used: A time series (1900-2015) of DE, Material use, NAS and DPO by Kraussman et al. (2018)[54] and projections of stock-related variables, i.e. primary and secondary stock-building materials, end-of-life waste from stocks and final waste after recycling by Wiedenhofer et al. (2019).[55] The two datasets are combined to get a consistent time series for key variables up to 2021 and the ratio of demolition and discard (calculated as GAS - NAS) to the DMC of non-metallic minerals estimated. This ratio is a proxy for the average relationship between the inflow of stock-building construction materials and the amount of C&DW generated and it is used as a model constraint for the calibration of C&DW estimates (including that which is destined to recycling). For each country and year, the ratio between the DMC of non-metallic minerals and C&DW has to be equal or higher than the global average. This constraint is not applied to the countries with bottom-up corrections for the amount of C&DW.

The generalised formula for the calculation of waste treated volumes is the following:

[53] Stadler, K., Wood, R., Bulavskaya, T., Södersten, C., Simas, M., Schmidt, S., Usubiaga, A., Acosta-Fernández, J., Kuenen, J., Bruckner, M., Giljum, S., Lutter, S., Merciai, S., Schmidt, J., Theurl, M., Plutzar, C., Kastner, T., Eisenmenger, N., Erb, K., ... & Tukker, A. (2021). EXIOBASE 3 (3.8.1) [Data set]. Zenodo. doi:10.5281/zenodo.4588235
[54] Krausmann, F., Lauk, C., Haas, W., & Wiedenhofer, D. (2018). From resource extraction to outflows of wastes and emissions: The socioeconomic metabolism of the global economy, 1900–2015. *Global Environmental Change*, 52, 131-140.
[55] Wiedenhofer, D., Fishman, T., Lauk, C., Haas, W., & Krausmann, F. (2019). Integrating material stock dynamics into economy-wide material flow accounting: concepts, modelling, and global application for 1900–2050. *Ecological Economics*, 156, 121-133.

$$was_{trt}(tonne) = was_{gen}(tonne) * was_{coll}(\%) * was_{trt}(\%)$$

Where the volume of waste treated $was_{trt}(tonne)$ is the product of the volume of waste generated $was_{gen}(tonne)$, the average collection rate $was_{coll}(\%)$ and the average treatment share $was_{trt}(\%)$ for a particular waste treatment type. For some countries, the sum of the waste treatment rates does not add up 100%: the remainder is assumed to be unaccounted waste.

4.3.1.2 Data sources

The WaW database compiles solid waste management data from various sources and publications for analytical purposes. The database mainly focuses on MSW, which includes residential, commercial and institutional waste. SW, which encompasses industrial, medical, hazardous, electronic, and C&DW is also compiled to the extent possible. Actual values rather than estimates or projections are prioritised, even if it requires the use of older data. The data reported are predominantly from 2011 to 2017, although overall data span about two decades. Within a single country, data availability may cut across several years. Furthermore, when a year range is reported in the original source, the final year of the range is provided in this document's data set. Overall, this translates into highly fragmented and heterogeneous data points from a temporal perspective. Waste collection coverage data are reported according to multiple definitions: amount of waste collected, number of households served, population served or geographic area covered. Waste treatment and disposal includes recycling, composting, anaerobic digestion, incineration, landfilling, open dumping and dumping in marine areas or waterways. Given the variability of types of landfills used, data were collected for three types of landfills: sanitary landfills with landfill gas collection systems, controlled landfills that are engineered but for which landfill gas collection systems do not exist or are unknown, and uncategorised landfills. In cases where disposal and treatment percentages did not add up to 100% or where a portion of waste is uncollected, the remaining amount was categorised as waste 'unaccounted for.' Waste not accounted for by formal disposal methods, such as landfills or recycling, was assumed to be dumped. Waste that is disposed of in waterways and that is managed in low- and middle-income countries in 'other' manners was also assumed to be dumped. Reported collection and treatment rates refer to MSW only.

The OECD data explorer[56] [57] was used as the main source for up-to-date MSW and hazardous waste data. Eurostat was used to update EU countries with great accuracy. For SW, waste generation data was sourced from env_was_gen.[58] Waste treatment rates were calculated from the env_was_trt dataset which grants more control than the env_wasoper dataset over waste stream to be included. For MSW, the env_wasmun[59] dataset was used instead. Both generated

[56] OECD. (2025). Municipal waste: generation and treatment. OECD Environment Statistics (Database). doi:10.1787/data-00601-en

[57] OECD. (2025). Waste - Hazardous waste: generation and movements. OECD Environment Statistics (Database)

[58] Eurostat. (2024). Generation of waste by waste category, hazardousness and NACE Rev. 2 activity (Data code: env_wasgen). doi:10.2908/env_wasgen

[59] Eurostat. (2025). Municipal waste generation and treatment (Data code: env_wasmun). Retrieved from: Eurostat website

waste streams and treatment types were mapped to the high-level WaW categories using custom mapping tables. Secondary and organic waste fractions (including related treatment types) were not included in the calculation. Each datapoint in the waste module could be corrected using bottom-up waste data. For simplicity, only one year is typically collected and the nowcasting logic is applied, if relevant. This has proven especially important for the industrial and C&D waste generation and treatment rates, especially for the big economies. Below is the list of sources for individual countries' bottom-up data collected during this study:

- Australia (AUS): C&D and industrial waste generation and treatment[60]
- Canada (CAN): C&D[61] and industrial waste generation and partial treatment[62]
- China (CHN): MSW generation,[63] treatment,[64] and C&DW generation and treatment (median of estimates from different sources),[65] [66] [67] industrial waste generation and treatment[68]
- India (IND): C&DW generation[69] and MSW treatment[70]
- Indonesia (IDN): Total waste treatment[71]
- Japan (JPN): C&DW generation[72]
- Russia (RUS): Industrial waste generation[73]
- South Africa (ZAF): C&DW generation[74]
- South Korea (KOR): C&DW and industrial waste generation,[75] MSW treatment,[76] and SW treatment[77] (K-eco)

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[60] Australian Bureau of Statistics. (2020). Waste account, Australia, experimental estimates. Retrieved from: ABS website
[61] Government of Canada. (n.d.). Reducing municipal solid waste. Retrieved from: Government of Canada website
[62] Statistics Canada. (n.d.). Table 38-10-0032-01 Disposal of waste, by source. doi:10.25318/3810003201-eng
[63] National Bureau of Statistics of China. (2022). *Collection, Transport and Disposal of Consumption_Waste in Citie*s. Retrieved from: National Bureau of Statistics China website
[64] National Bureau of Statistics of China. (2023). *China statistical yearbook*. China Statistics Press. Retrieved from: National Bureau of Statistics China website
[65] Invest Northern Ireland. (2022). *Insights on construction and demolition waste recycling industry report.* Retrieved from: InvestNI website
[66] Zheng, L., Wu, H., Zhang, H., Duan, H., Wang, J., Jiang, W., Dong, B., Liu, G., Zuo, J., & Song, Q. (2017). Characterizing the generation and flows of construction and demolition waste in China. *Construction and Building Materials, 136*, 405-413. doi:10.1016/j.conbuildmat.2017.01.055
[67] Zhang, N., Zheng, L., Duan, H., Yin, F., Li, J., Niu., Y. (2019). Differences of methods to quantify construction and demolition waste for less-developed but fast-growing countries: China as a case study. *Environmental Science and Pollution Research, 26,* 25513-25524. doi:doi.org/10.1007/s11356-019-05841-4
[68] National Bureau of Statistics of China. (2023). *China statistical yearbook*. China Statistics Press. Retrieved from: National Bureau of Statistics China website
[69] Government of India Ministry of Environment, Forest and Climate Change. (2016). Environment ministry notifies construction and demolition waste management rules for the first time. Retrieved from: Government of India website
[70] Central Pollution Control Board Delhi. (2016). *Annual report 2020-21 on implementation of solid waste management roles, 2016.* Retrieved from: CPCB website
[71] SIPSN. (n.d.). Capaian kinerja pengelolaan sampah. Retrieved from: SIPSN website
[72] Zhao, Q., Gao, W., Su, Y., Wang, T., & Wang, J. (2023).How can C&D waste recycling do a carbon emission contribution for construction industry in Japan city? *Energy and Buildings, 298,* 113538. doi:10.1016/j.enbuild.2023.113538.
[73] Federal State Statistics Service. (n.d.). Для безопасности Ваших данных Росстат перешёл на российские SSL - сертификаты. Retrieved from: Rosstat website
[74] De Villiers, W., Mwongo, M., Babafemi, A. J., & Van Zijl, G. (2024). Quantifying recycled construction and demolition waste for use in 3D-printed concrete. *Recycling, 9*(4), 55. doi:10.3390/recycling9040055
[75] Statista. (2025). Distribution of waste generated in South Korea in 2023, by type. Retrieved from: Statista website
[76] KOSIS. (2021). Waste generation status_household waste. Retrieved from: Statistics Korea website
[77] Korea Environment Corporation. (2021). *Closer to people and nature*. Retrieved from: K-Eco website

- Turkey (TUR): Industrial waste generation[78]
- United States (US): C&DW and industrial waste generation,[79] industrial waste treatment[80]

4.3.1.3 Gaps and limitations

Despite best efforts to guarantee the quality and reliability of the figures in the database, they should be used with great care due to the extensive use of assumptions and the shortcomings underlying this approach. The main limitations and avenues for future improvement are listed below:

- The choice of gross output—and more generally, monetary data—to extrapolate SW has many shortcomings: for example, the exclusion of waste generation by the informal economy and the overestimation of waste generation for geographically small countries with high GDP. C&DW could be better estimated using a dynamic stock and flow model;

- For EU countries, the application of a standard approach to the calculation of volumes of treated waste treatment rates (i.e. multiplication of waste generation with treatment rates) results in discrepancies in overall volumes of waste treated between the engine and env_wastrt. Moreover, for EU countries treatment rates are calculated 'at the treatment facility gates', thus including imported and excluded exported waste, while waste generated is just that produced within territorial borders (excluding imported and including exported waste). For non EU countries, this information is not available and thus this effect remains unknown;

- The application of the same collection and treatment rates for MSW and SW could be improved by the use of specific rates for each type for all countries;

- The use of waste treatment sectors' gross monetary output for the development of scaling factors could be improved by the selection of a more specific factor such as investment in waste treatment technologies.

While recovered materials were either reported in waste statistics or could be directly quantified, this was not possible for other circular strategies such as the extension of product lifetimes, refurbishment, remanufacturing, or sharing. As already mentioned in the *CGR Measurement Framework*, these strategies would result in an increase of the service lifetime of in-use stocks and potentially a stabilisation of in-use stock growth, as indicated by the NAS. Thus, even though these strategies are difficult to measure directly, their effects on the size of inflows, additions to stock, and outflows can be substantial and are observable via the *CGR Measurement Framework* .

[78] Türkiye İstatistik Kurumu. (2023). Atık İstatistikleri, 2022. Retrieved from: Government of Turkey website
[79] Estimate based on: Krones, J., Chertow, M., & Li, X. (2020). Making up for lost time (and space): Quantifying non-hazardous industrial waste generation in the U.S. Environmental Research and Education Foundation. Retrieved from: EREF website
[80] Set as a weighted average between the C&D recycling rate from: US EPA. (n.d.). Construction and demolition debris: Material-specific data. Retrieved from: EPA website and the MSW recycling rate from: US EPA (n.d.). National overview: Facts and figures on materials, wastes and recycling. Retrieved from: EPA website

4.3.2 Module 3.2: Waste trade

4.3.2.1 Description

ITCr represents a country's effort to produce and consume secondary materials (including waste destined for recycling and by-products) collected in another country and later imported for domestic deployment. When adjusting the amounts of recycled waste in treatment operations by imports and exports of secondary materials, the country that uses the secondary material gets the 'credit' for contributing to the worldwide saving of primary raw materials. This perspective is closer to the national accounts' logic in which most re-attributions are directed towards final use.

For more extensive information on trade in secondary materials and how this influences the ITCr, refer to Box three in *Methodology for Nations*.

4.3.2.2 Data sources

To calculate the amounts of imported and exported waste and by-products, Eurostat has identified a list of Combined Nomenclature (CN) codes that can be considered as such.[81] [82] For application to non-EU countries, Circle Economy has developed a mapping table between the CN and Harmonised System (HS) classification that replicates this methodology on international bilateral trade databases such as BACI.[83]

4.3.2.3 Gaps and limitations

Due to the lack of available statistics, domestic use and trade of reused goods as well as other types of 'inner flows' such on-site recycling is currently poorly or not at all captured in the analysis. Furthermore, while trade in by-products can be estimated from international trade databases, the production for domestic use of by-products is missing. At the country-level this can result in an overly negative consumption of by-products due to the lack of the 'domestic' component and, in some cases, overall negative consumption of secondary materials.

4.3.3 Module 3.3: Dissipative uses and losses

4.3.3.1 Description

Some materials—such as manure, fertilisers or sewage sludge—are deliberately dissipated into the environment because dispersal is an inherent quality of product use or quality and cannot be avoided.[84] The explicit accounting of these flows is only relevant in the context of the traditional approach while in the extended one they are estimated as a residual item within processed

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[81] Eurostat. (2022). ANNEX - List of CN-codes used for the calculation of trade in waste. Retrieved from: Eurostat website

[82] Eurostat. (2023). ANNEX - List of CN-codes used for the calculation of trade in recyclable raw materials. Retrieved from: Eurostat website

[83] Gaulier, G. & Zignago, S. (2010). BACI: International trade database at the product-level. The 1994-2007 version. CEPII Working Paper, N°2010-23. Retrieved from: CEPII website

[84] Matthews, E., Amann, C., Bringezu, S., Fischer-Kowalski, M., Hüttler, W., Kleijn, R., ... & Weisz, H. (2000). The weight of nations. Material outflows from industrial economies World Resources Institute, Washington.

outputs. In the traditional approach, all the subcategories of MF7.4 except for 'Pesticides', 'Seeds', 'Salt' and other thawing materials spread on roads such as grit, and 'Solvents, laughing gas and others' are accounted for.

4.3.3.2 Data sources

A variety of sources were used for the compilation of the dissipative uses:

- Organic fertilisers using FAOSTAT QCL livestock data, regionalised volatile solid (VS) coefficients and manure production coefficients from Annex 10A.2 from the IPCC Methodology;[85]
- Mineral fertilisers using FAOSTAT RFN data;[86]
- Sewage sludge using UNFCCC data under '3.D.1.b.ii Sewage Sludge Applied to Soil' together with conversion factors (Non-Annex I countries were estimated through interpolation);
- Compost using UNFCCC data under '5.B.1 Biological treatment of solid waste—composting' together with conversion factors (Non-Annex I countries were estimated based on WaW composting rates applied to MSW).

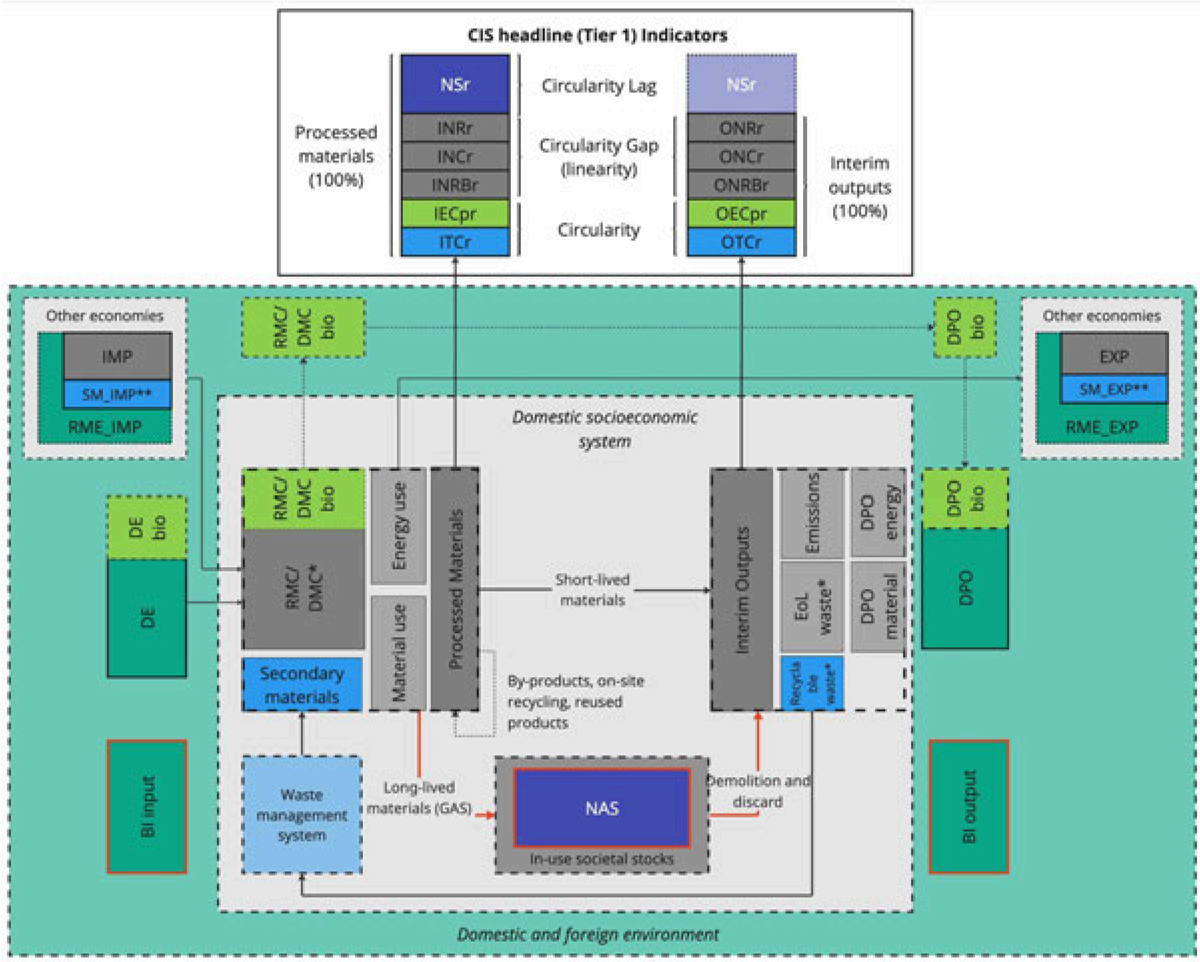
4.3.3.3 Gaps and limitations

Although some dissipative uses and all dissipative losses were not included, their contribution to overall processed output is minimal.

[85] IPCC. (2006). Chapter 10: Emissions from livestock and manure management. In *IPCC Guidelines for National Greenhouse Gas Inventories.* Retrieved from: IPCC website
[86] FAO. (2024). FAOSTAT: Food balance sheets (RFN). FAOSTAT. [Accessed on 24/11/2024]. Retrieved from: FAO website

4.4 Module four: Balancing items and stock additions

Figure five *pictures a simplified extended EW-MFA framework based on Mayer et al. (2018) with elements of Module four highlighted.*



4.4.1 Description

Although bulk water and air flows are excluded from EW-MFA, material transformations during processing may involve water and air exchanges which significantly affect the mass balance. Balancing items (BIs) are estimations of these flows, which are not part of DE, DPO or NAS, because they are not included in their definitions. BIs mostly refer to the oxygen demand of various combustion processes (both technical and biological ones), water vapour from biological respiration, and from the combustion of fossil fuels containing water and/or other hydrogen compounds. In the compilation of these flows, only a few quantitatively important processes are taken into account and the flows are estimated using generalised stoichiometric equations. The explicit accounting of these flows is only relevant in the context of the traditional approach, while in the extended approach, inflows and outflows are inherently estimated at the net of the BIs. In the traditional approach, their inclusion is extremely important for an accurate estimation of NAS. The inclusion/exclusion of BIs as well as the different approach to the closure of mass balance and the estimation of NAS are the main distinctions between the traditional and the extended EW-MFA approach. This can be best observed by comparing the mass balancing formulas of the two approaches (see Table three).

$$NAS_{trad} = DMC + BI_{in} - BI_{out} - DPO$$

$$NAS_{ext} = GAS - D\&D$$

$$GAS = PM * mUse\_stk$$

$$D\&D = W\_mUse - (mUse - GAS - Wu_{mUse})$$

For more extensive information on the elements in this module refer to section Module four: Material balance and stock accounts of the *CGR Latin America and the Caribbean* methodology document.

4.4.2 Data sources

Due to the different nature of the calculations between the traditional and extended approach, the data sources are also different. In the traditional approach, BIs are calculated using FAOSTAT QCL and the UN population prospects datasets for items related to livestock and human respiration while those related to combustion processes and water content are estimated using DMC derived from the IRP's TCCC dataset. NAS is estimated as the residual BI. In the extended MFA approach, instead, the estimation of GAS and demolition and discard is based on variety of sources: PM derived from the IRP's TCCC dataset and secondary materials from Module three: Waste, material and energy use coefficients based on Mayer et al. (2018), waste composition shares from Haas et al. (2020), FAOSTAT food balances, and UNSTAT energy balances.

4.4.3. Gaps and limitations

For the traditional approach, only the most important BIs are calculated representing about 90% of the total (based on EU countries data) for both the input- and output-side.

For the extended approach, even though it measures flow at the net of the BIs, a number of gaps and limitations should be considered. Although these limitations cut across several modules, it was decided that they should be grouped here as they all converge into the estimation of NAS :

- An integral application of the extended MFA approach would require the conversion of metal ores from DE into metal content and extractive waste (tailings). Extractive waste should then be directly ascribed to interim output while the material use of metals should be expressed in metal content. Currently, all flows are instead expressed as metal ores, therefore significantly inflating the size of the metal ores resource group across all indicators;

- Proxy values from Haas et al. (2020) for the composition of waste flows are applied to all current waste streams. These shares are based on the composition of the ’discard and demolition’ flow for the year 2015. Therefore, these compositions do not consider waste generated by short-lived products and dissipative losses (‘dissipative losses and processing waste’ in the Haas et al. (2020) model) as this would lead to an overestimation of the biomass fraction. We make an exception for metal ores, for which ‘dissipative losses and processing waste’ are included, since extractive waste (tailings) is directly ascribed to interim outputs and the metals in ’discard and demolition’ are expressed in metal content while tailings are—in theory—included in the engine’s waste treatment data;
- Waste from energy use largely constitutes animal and food waste, and in a smaller part, combustion waste and sludges. Since manure, crop-residues and the composted share of MSW are not included in the waste treatment data from the WaW database (and bottom-up corrections), in this simplified approach we assume that all waste from the WaW database (and bottom-up corrections) recorded in the engine originates from material use.

5. THE WAY FORWARD

As the *CGR Measurement Framework* continues to evolve, several key areas require further development and refinement. These improvements will enhance the comprehensiveness, accuracy, and applicability of the methodology, ensuring that it remains a reliable tool for assessing global circularity. The key areas of improvement can be grouped into three categories: the implementation of the conceptual framework, the measurement framework, and the CIS.

5.1 Enhance the conceptual framework

Implementing the conceptual framework in line with the *CES Guidelines*: The current CIS scope primarily focuses on the material dimension of the circular economy, specifically the aspect of 'Material life cycles and value chains'. To fully implement the conceptual framework in line with the *CES Guidelines for Measuring Circular Economy, Part A: Conceptual Framework, Indicators and Measurement Framework*, additional dimensions will need to be integrated—such as environmental impacts, employment, and financial aspects. The expansion will follow a similar approach to that used for the 'Material life cycles and value chains' aspect:

- **Step 1:** Evaluate the indicators proposed in the *CES Guidelines* for other circular economy aspects—'Interactions with the environment', 'Responses and actions', and 'Socioeconomic opportunities'. This assessment will consider criteria such as relevance and measurability to select the most appropriate indicators for inclusion in the CIS. Indicators identified as 'core' in the Guidelines will be treated as highly relevant by default.

- **Step 2:** Identify alternative indicators for areas marked in the *CES Guidelines* as 'placeholders' or where the most relevant indicators are yet to be defined. This includes incorporating as complementary or substitute indicators, including metrics, such as:
    - The number of direct and indirect circular jobs, measured using the Circular Job Analysis approach developed by Circle Economy and UNEP, with an update currently in development with ILO-WB;[87]
    - The amount of investments in circular activities or businesses, as guided by the International Finance Corporation (IFC)—which assessed the landscape of sustainable finance and streamlined various existing frameworks into a simplified guideline for classifying circular investments[88]—and first measured by Circle Economy in the *Circularity Gap Report Finance.*[89]

[87] Muñoz H, M. E., Novak, M., Gil, S., Dufourmont, J., Goodwin Brown, E., Confiado, A., & Nelemans, M. (2022). Tracking a circular economy transition through jobsCircular Economy Transition Through Jobs: Method development and application in two citiesDevelopment and Application in Two Cities. *Frontiers in Sustainable Cities, 3*, 787076.
[88] IFC Harmonised Circular Economy Finance Guidelines, to be published Q4 2025.
[89] Circle Economy. (2025). *The circularity gap report finance*. Retrieved from: CGR website

- **Step 3:** For the selected long-list of ideal indicators, identify data sources and/or calculation methods. Where no suitable source or method exists, the indicator will be retained as a reference, and a placeholder will be proposed. This process will be iterative, leading to the development of:
    - A long-list of ideal indicators, and
    - A short-list of suitable indicators for implementation.
- **Step 4 (Optional):** As with the 'Material life cycles and value chains' aspect, develop headline indicators for the new dimensions. This may involve techniques such as normalisation or weighting to enable comparability and integration across aspects.

Strengthening Tier two and Tier three Indicators: Due to existing data limitations, certain complementary (Tier two) and contextual (Tier three) indicators are absent or temporarily replaced with proxies in the *CGR 2025*. Developing a more systematic approach for integrating lower-tier indicators will improve the framework's analytical depth and applicability.

5.2 Refining the measurement framework

Implementing country-level extended MFA: A critical improvement is the full application of the extended MFA approach at the country level. This requires higher-resolution data to differentiate waste streams by origin (material versus energy use) and composition. Additionally, improving the tracking of energy carriers (for example, moving from energy balances to Physical Energy Flow Accounts) and reconciling traditional and extended MFA results through optimisation algorithms will enhance accuracy.

Advancing Module three: Waste: Given the complexity and data scarcity in waste tracking, the waste module remains a priority for improvement. The following aspects require attention:

- Quantifying waste from unused domestic extraction: This is essential for harmonising input- and output-side statistical data collection;
- Improving coverage of waste generation and treatment data: Many data-scarce countries currently assume that MSW treatment rates apply to all solid waste streams, leading to inaccuracies. Developing bottom-up corrections or systematic estimations will enhance precision;
- Addressing inconsistencies in waste treatment rate calculations: Existing datasets often record waste treatment rates under different principles, leading to potential overestimations (such as in EU countries) or underestimations elsewhere. A structured evaluation and correction process is necessary.

Reducing dependence on model constraints: Gradual refinement of the framework, including the adoption of the MISO v2 model, will eventually eliminate the need for top-down constraints that align results with global models.

Accounting for by-products and reused products: Improved estimation techniques and the integration of new datasets will allow for more precise accounting of domestic and traded by-products and reused materials.

5.3 Strengthening the Circularity Indicator Set

Improving r**epresentation of waste management processes:** The current EW-MFA framework assumes that materials available for recycling directly translate into secondary materials used in the market. This simplification ignores sorting and processing losses and does not differentiate between different end-of-life waste age cohorts. Increasing the level of detail in the waste management process will significantly improve stock-flow dynamics representation.

Developing criteria for sustainable biomass management: Establishing clear input- and output-side criteria for defining sustainably managed and regenerative biomass will enhance measurement accuracy. This will involve identifying relevant datasets (such as certification schemes) or methodologies (such as Substance Flow Analysis) that support the assessment of sustainability in biomass use.

Resolving the 'net extraction abroad (NEA) issue' in national circularity assessments: Country-level circularity results can be calculated using either DMC or RMC. While RMC better reflects a country's material extraction pressure, its application to the CIS is complex due to unresolved methodological challenges (see section 'NEA issue' in Appendix A of *Methodology for Nations*). Addressing this remains a key priority.

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