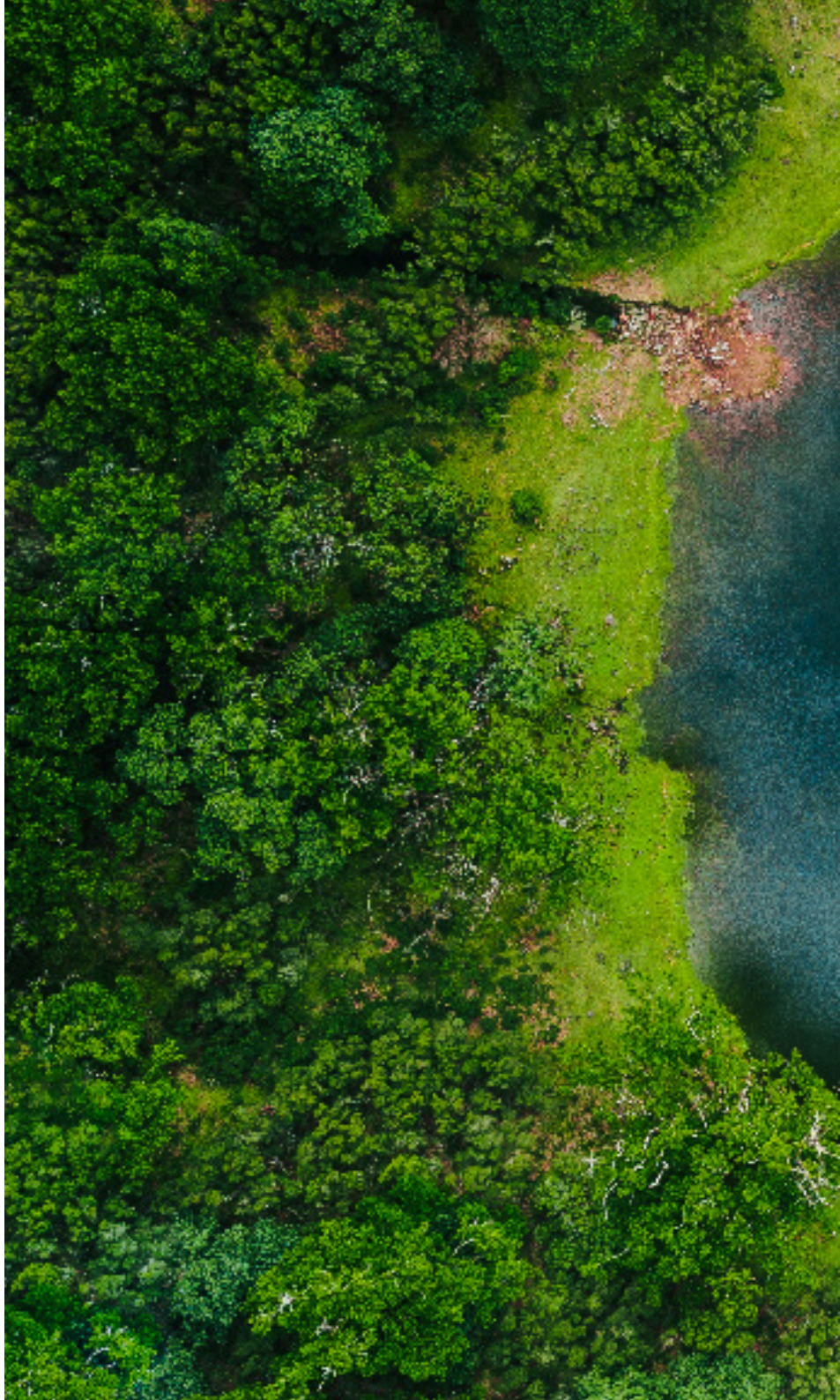
Deloitte.

CIRCLE ECONOMY

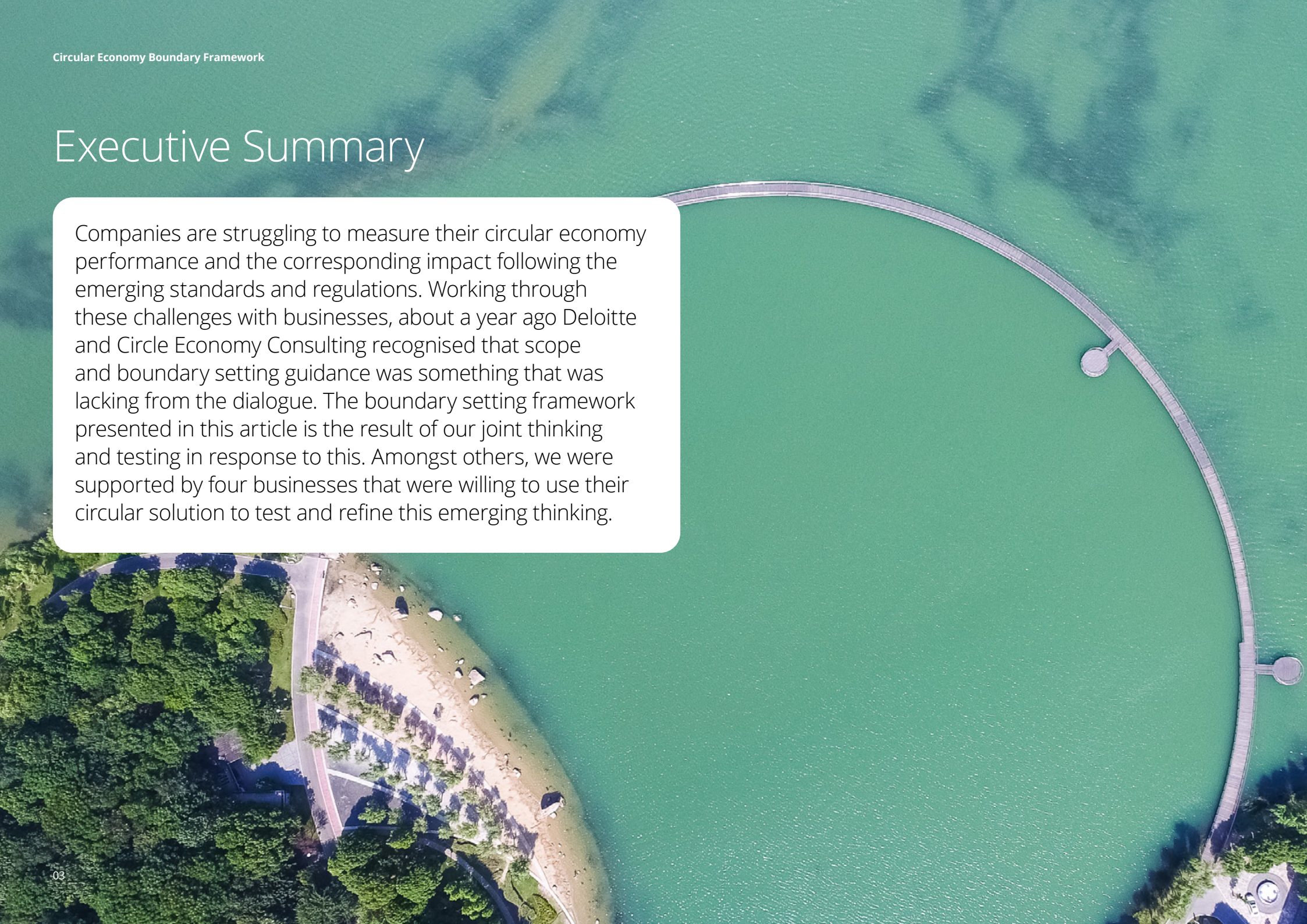
Circular Economy Boundary Framework

Report
Setting circularity scopes for impact and material measurements innovation, May 2025

Contents



Executive Summary



Companies are struggling to measure their circular economy performance and the corresponding impact following the emerging standards and regulations. Working through these challenges with businesses, about a year ago Deloitte and Circle Economy Consulting recognised that scope and boundary setting guidance was something that was lacking from the dialogue. The boundary setting framework presented in this article is the result of our joint thinking and testing in response to this. Amongst others, we were supported by four businesses that were willing to use their circular solution to test and refine this emerging thinking.

A well-defined boundaries framework is an essential building block for businesses aiming to enhance circularity efforts by establishing clear operational boundaries that allow them to effectively define their control over resource flows These resource flows can represent profound sustainability and economic impacts, such as emission of greenhouse gasses, negative impacts on biodiversity, pollution, or dependency of critical materials. The draft Circular Economy Boundary Framework (CEBF) delineates four distinct scopes—A, B, C, and D—each representing varying degrees of influence and control over circularity metrics, see figure 1.

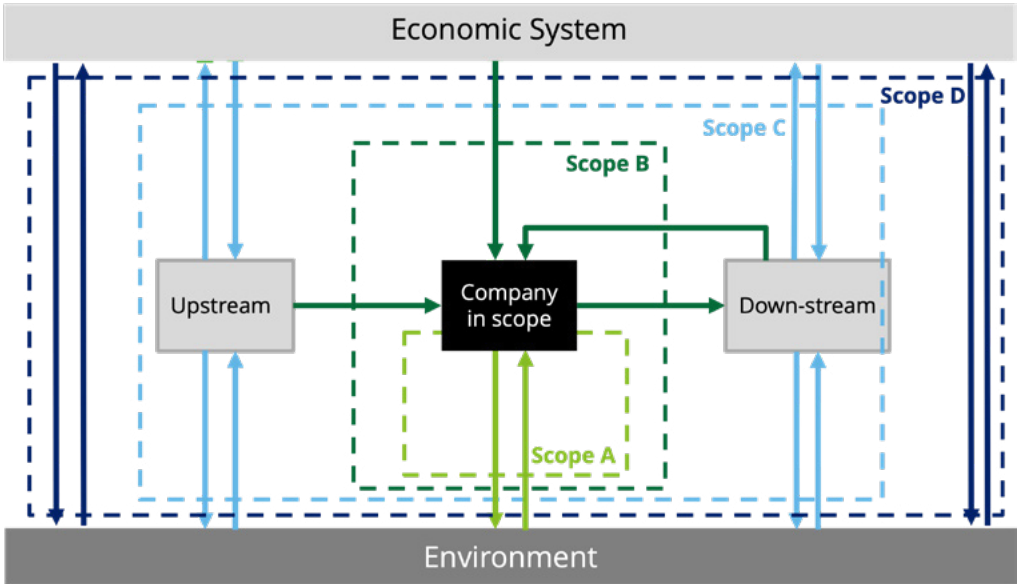
Scope A - This scope encompasses the resource flows that a company directly manages, including the extraction of natural resources and the disposal of waste. Understanding this scope is vital for assessing immediate environmental impacts.

Scope B: Direct Control within the Value Chain - This includes material flows that the company directly influences within its supply chain, such as resources sourced from suppliers and products delivered to customers. Companies can leverage this scope to enhance procurement strategies and product design.

Scope C: Indirect Control across the Value Chain - This scope extends beyond the company's direct operations and encompasses the resource flows influenced by the company's decisions throughout the entire value chain. Understanding this scope allows businesses to take responsibility for their broader supply chain impacts.

Scope D: Influence on the Wider Ecosystem - Capturing macro-level resource flows, this scope assesses a company's role in shaping circular consumption patterns and impacting resource use across sectors.

Figure 1 Schematic overview of the scopes in the value chain



To illustrate the practical application of the CEBF, four case studies highlight innovative circular solutions implemented by prominent organisations:

Signify: Light-as-a-Service

This case study demonstrates how a Product-as-a-Service (PaaS) model can enhance the circular economy performance of businesses over time, showcasing the effective management of Scope B and C flows to promote resource efficiency.

Gestamp: Closed Loop Recycling of Manufacturing Waste

This example illustrates how closed-loop recycling initiatives can lead to upcycling, assessing the impact on greenhouse gas emissions and upstream resource use within Scope B and C.

JLR: Repurposing EV Batteries

By examining the remanufacturing and refurbishment of electric vehicle batteries, this case study highlights the differences and benefits of Scope B, C, and D in measuring avoided resource use and increasing material productivity.

Hempel: High-Performance Coatings

This case highlights how enabling solutions can help customers transition towards circular practices, demonstrating the broader impacts captured in Scope D.

The findings from these case studies underscore the necessity of setting appropriate system boundaries in the assessment of circular economy performance. The draft CEBF can be a useful strategic tool for organisations to enhance accountability, minimize risks, drive innovation, and foster sustainable practices. By applying clear boundaries, businesses can better navigate the complexities of linear and circular value chains, ultimately contributing to a more sustainable and resilient economic landscape with less dependency on scarce, critical or harmful resources.

The Circular Economy Boundary Framework is not a finalized framework and further development, testing and standardisation is needed. Through the publication of this framework, Deloitte and Circle Economy Consulting hope to move the discussion forward and inspire others to review and improve it, or propose alternatives. The path to circularity begins with clear communication, accountability and taking responsibility —let us set them together.

The need for better metrics for circular economy

As you engage with this article, consider the device before you. It serves as a testament to the intricate systems of resource extraction, processing, and consumption that allow us to live our lives the way we do. One laptop may require up to 1,200 kg of materials being mined and processed – mostly harmless waste rock, but also substantial amounts of (hazardous) mining waste, critical materials, and metals with high CO_2 footprints. Throughout its life cycle, the laptop will consume large amounts of electricity, and allow you to access servers that consume even more materials and energy. The environmental and societal impacts of these processes are profound, primarily stemming from resource consumption occurring upstream and downstream of the assembly lines where your laptop had taken its final form. Now consider the company operating the assembly line. Which resources should that company consider when reporting on the circular economy performance of your laptop? What is a circular laptop?

Despite the growing emphasis on sustainability, many businesses continue to grapple with the ambiguity surrounding circularity measurement. The myriad existing methods can lead to confusion, often undermining effective decision-making. At the same time, gaps in the current methodologies leave analysts to develop their own approaches, leading to incomparable results. This situation underscores the necessity for a unified, standardised methodology that enables organisations to systematically evaluate the (impacts of) material flows in their operations, value chains, and wider ecosystem and utilize circular economy metrics to their benefit.

Where is your circular economy impact?

Measuring circular economy performance within today's intricate global value chains presents several challenges. The complexity of these systems, combined with the absence of universally accepted reporting standards and methodologies, often results in the misrepresentation of circular economy performance. Furthermore, to compare the impact of solutions or businesses it is important that the scope of the activities measured is similar.

For businesses wanting to measure and report Greenhouse Gas (GHG) emissions, the GHG Protocol[1] (GHG-P) introduced standardised scopes to measure emissions from the own operations of businesses or across the value chain. This has helped businesses to speak the same language with regards to GHG emissions, measure comparable parts in the value chain, and work together on solutions. In addition, it has helped to set clear targets for companies to reduce emissions.

> "A clear scoping framework for circularity is essential to shaping Hempel's sustainability strategy. Materials are our primary lever for creating sustainability impact, so having a well-defined scope will enable us to map material flows across the value chain, identify impact hotspots, and determine where and how to act—collaboratively and strategically—to maximize sustainable value creation for our customers."
>
> **Yorgos Chalkias** - Head of Sustainability, Decorative Business Hempel

To measure and monitor resource flows across the value chain and beyond, we explored the option of applying the same scopes - Scope 1, 2, and 3 and the concept of avoided emissions - could work for Material Flow Analysis (MFA).

Unfortunately, there is complexity with this approach. The standardised scopes introduced by the GHG-P focus on emissions that are measured at specific points in time and space, which does not align with the continuous nature of materials flowing through a (circular) economy. In addition, certain circularity practices are currently even penalized in the GHG framework.[2]

This is where this boundary framework for circular economy scopes comes in, resulting from a collaboration between Deloitte and Circle Economy Consulting, and discussed with thought leaders and experts in the field of circular economy. The framework proposes a new way to uniformly measure resource flows from and to the environment, in and out of a company, through the value chain and from and to the wider economic system.

[1] Greenhouse Gas Protocol

[2] Ellen MacArthur Foundation 2025, Improving climate emissions accounting to accelerate the circular economy transition

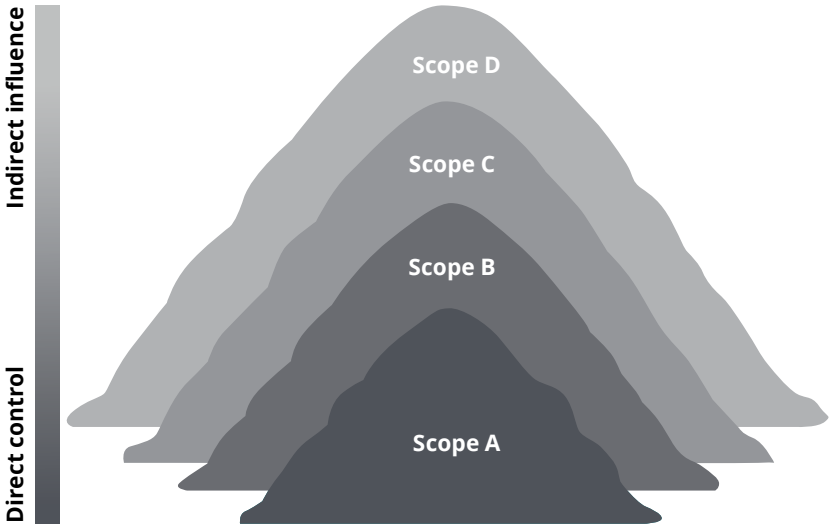
The Circular Economy Boundary Framework

The Circular Economy Boundary Framework (CEBF) provides a robust and comprehensive method for measuring and reporting circular performance. It defines clear operational boundaries that outline the various scopes of resource flows representing a company's control and influence.

Overview of the CEBF Scopes

The CEBF introduces four distinct scopes—A, B, C, and D—each serving as a critical lens through which an organisation could assess their circularity efforts within their organisation, in their value chain and in the wider economic system. Figure 2 illustrates the increasing resource use as you zoom out from Scope A to Scope D. The delineation of these scopes is essential for ensuring clarity and enabling organisations to accurately measure their impacts.

To ensure that this framework also supports effective decision making, they represent different spheres of influence that a company has on the quality and performance of individual material flows, from direct control (the company has full decision power) to limited influence (decision power lies mostly with other organisations). Lastly, each scope also has different data needs, making it easier for analysts to understand what data is needed to answer which questions on circular economy performance.



Scope D: Indirect Influence– material use within other value chains
Materials that are used within value chains that cannot be attributed to the organization's activities, but are indirectly influenced by the organization's activities.

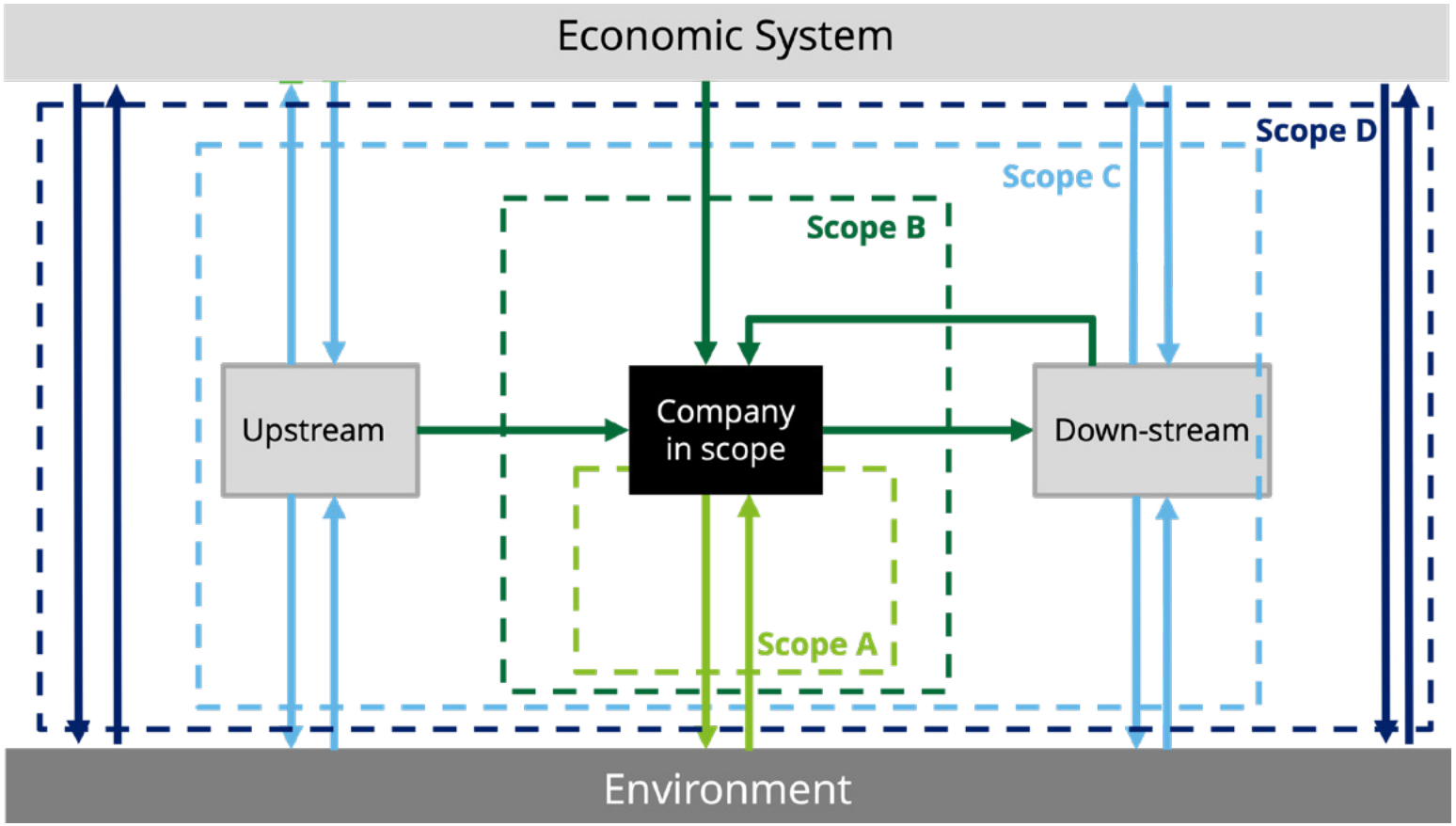
Scope C: Indirect control – material use within the value chain
Materials that are used within the value chain and can be attributed to organizations' activities, but do not come under direct control of the organization.

Scope B: Direct control - interactions with the value chain
Materials that are provided to the organization through direct suppliers, or are provided to value chain partners by the organization itself.

Scope A - Direct control - interactions with the environment
Materials that are extracted from the environment, or returned to the environment, by the organization itself.

In figure 3 the scopes are plotted on a simplified value chain. The figures shows that the scopes overlap one another. When using the scope to measure, monitor and report it is important to keep the purpose of the application in mind. This will help prevent double counting or focusing on scopes which are less relevant for your company.

Figure 3 Schematic overview of the scopes in the value chain



Definition and application of the circular economy scopes	Scope A: Direct Control over the Environment	Scope B: Direct Control within the Value Chain	Scope C: Indirect Control across the Value Chain	Scope D: Indirect Influence on the Wider Ecosystem
Definition	This scope encompasses the resource flows that a company directly controls and result from direct interactions between the organisation and the environment.	Scope B encompasses material flows from and to other business that are directly controlled by the company , including resources sourced from suppliers and products delivered to customers.	Scope C includes resource flows that are part of the company's value chain and can be attributed to the company's activities, but never enter the company's direct operational control.	Scope D captures resource flows that a company influences but which fall outside of its immediate value chain, assessing the broader economic ecosystem's circular economy performance.
Significance	Understanding Scope A is crucial, as it represents the immediate environmental impacts of a company's operations, including the extraction of natural resources and the disposal of waste, waste water and emissions directly into the environment.	Scope B empowers organisations to manage their resource procurement strategies and product design processes, enabling them to enhance circularity through responsible sourcing and waste reduction.	Scope C is vital for understanding the broader environmental and social impacts associated with resource use, allowing companies to take responsibility for their supply chains and to collaborate with customers.	Scope D enables organisations to evaluate and clearly communicate their role in driving circular consumption patterns and reducing overall resource use across sectors.
Application	Companies in sectors such as mining, oil and gas, and agriculture are expected to have large Scope A flows. They must closely monitor these flows to mitigate negative environmental impacts and ensure compliance with regulations.	In sectors such as manufacturing and construction, organisations can leverage Scope B to identify opportunities for circular product designs that maximise resource efficiency and minimise waste generation.	For original equipment manufacturers (OEMs) and large retailers, Scope C provides insights into upstream and downstream impacts, enabling them to collaborate with suppliers and customers to enhance circularity efforts.	Businesses offering sustainable alternatives or circular economy solutions can leverage Scope D to demonstrate their positive impact or evaluate negative side effects on resource consumption beyond their own value chain(s).
Required data	Data to measure material flows in Scope A is often collected from your own operation managers.	Data to measure material flows in Scope B will have to be collected from your procurement department, sales teams and colleagues responsible for waste management	Scope C data will be more difficult to collect as this will require a certain level of transparency in the supply chain. Analysts might have to revert to sector averages, estimates from literature or public datasets to fill data gaps.	Material flows in Scope D can be very varied and will require analysts to have a good understanding of product performance, alternatives and substitutes, and the operations of their customers.

Four Circular Case Studies

This section presents four case studies that exemplify distinct circular economy approaches, highlighting their effectiveness and impact while demonstrating how different scopes of the Circular Economy Boundary Framework can be applied through various scenarios. Each case study offers a unique perspective on how businesses can measure and communicate the effectiveness circular solutions to enhance sustainability and drive economic benefits.

For each case study we started with Scope B, as this scope aligns with most reporting requirements like CSRD, however this scope does not always tell the full story or impact.

Company	Circular solution	Our case study shows...	We assessed...	We measured ...
Signify	Light-as-a-service	How PaaS models improve the circular economy performance of businesses over time	Scope B & C	Circular inflow*; circular outflow*; Resource use
Gestamp	Closed loop recycling of manufacturing waste	How closed loop recycling often leads to upcycling	Scope B & C	Circular inflow*; circular outflow*; impact on GHG emissions; Upstream resource use
JLR	Repurposing EV batteries	How remanufacturing and refurbishment lead can lead to avoided resource use	Scope B & D	Circular inflow*; circular outflow*; Material productivity*; Resource use
Hempel	High performance coatings	How enabling solutions help customers to become more circular	Scope B & D	Avoided resource use

*) methodology based on the Circular Transition Indicator (CTI) framework of the WBCSD

On the next pages we will describe the outcomes of the four case studies that were performed. For each case study, we built linear and circular scenarios, developed value chain maps, classified the most significant material flows to each of the four scopes, and calculated the improvement of the circular scenarios using various scopes and indicators. More details for each case study can be found in the fact sheets attached to the end of this document.

In figure 4 the customized (and simplified) value chain of JLR's Repurposing EV Batteries can be found as an example.

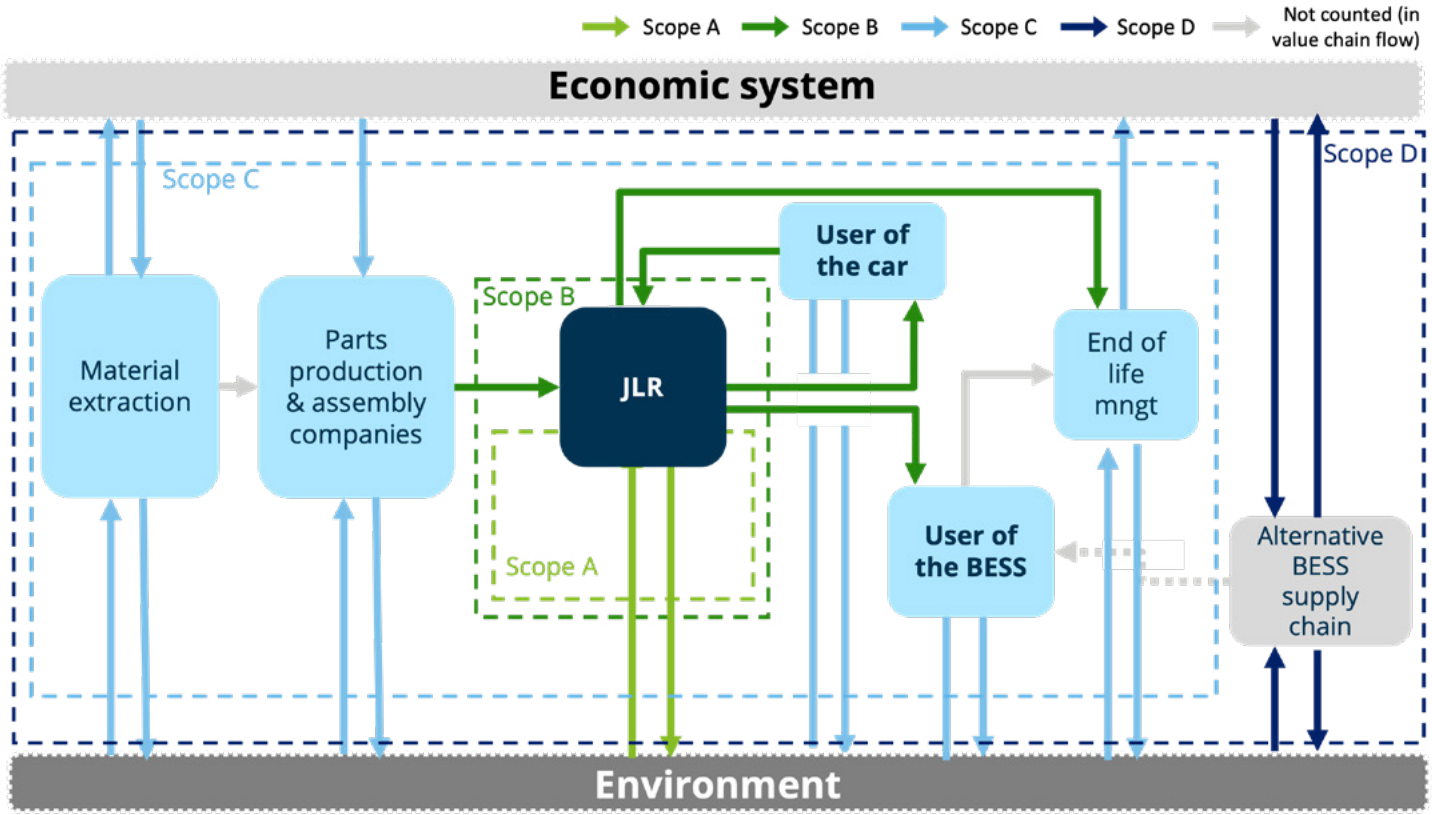


Figure 4 Example value chain - JLR repurposing EV batteries

Signify: Light-as-a-service

Signify, the world leader in lighting, is well-known for being a pioneer on the introduction of new so-called “Product-as-a-service" (PaaS) models – business models in which products are not sold to customers but are provided to them as part of a service or subscription. In the case of Signify, its Light-as-a-Service (Laas) model allows customers to pay for the light, not lighting equipment, that they use. This enables Signify to benefit from its more durable and high-quality products, which will require less replacements and an improved client relationship.

Scope B assessment:

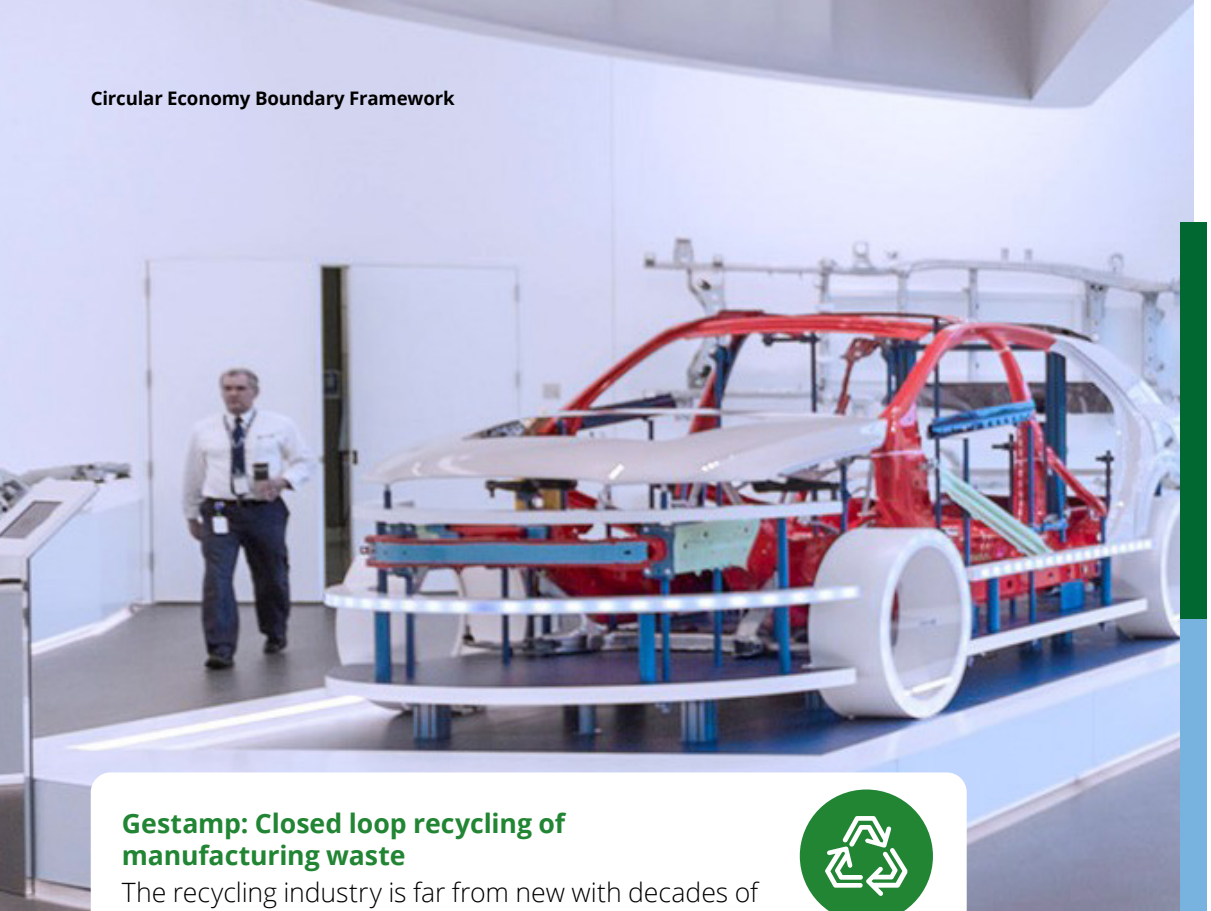
Obviously, introducing a PaaS model provides businesses – over time – with a significant number of returned products that can be reused, refurbished, or recycled. As the products are not sold to customers businesses running PaaS models retain ownership of the products. This means that they can’t report the returned products as circular inflows or outflows until they leave the company (for example, to be recycled).

When assessing the impacts of Signify’s LaaS model on its inflows and outflows in Scope B, the main benefit of this circular offering is the increased recycling rate as Signify can ensure recycling at the end-of-life of its products, and the increased access to secondary resources from its value chain partners. The Signify case also shows that it will often take some time before products that are part of a PaaS model return from customers in significant amounts and show up as part of a company’s performance report. For Signify, we assumed this could take up to 20 years. This shows that companies implementing PaaS models would do well to report not only on their company performance in scope B but also on the full life cycle of their products.

Scope C assessment:

As the number of products that return from customers for reuse or recycling as part of a PaaS model, the need of the company for new virgin feedstock to manufacture new products will decrease. This can be measured by assessing the overall resource consumption of the company (scope B) and its value chain (scope C). As expected, the Signify case study shows significant decreases in resource consumption over time. However, as Signify’s supply chains include various stages at which a lot of resources are wasted such as mining and metal processes, the reduction of resource use in Scope C is much more significant than in Scope B.

This shows that it is important for businesses with large and/or wasteful supply chains to consider reporting in scope C, as Scope B tends to underestimate the impact of PaaS models and other circular solutions that reduce the need for resource consumption.



Gestamp: Closed loop recycling of manufacturing waste

The recycling industry is far from new with decades of experience and innovation below their belt, but there are still significant inefficiencies in recycling that can be improved. Gestamp, as a major producer of components for the automotive industry, has taken the initiative to tackle such inefficiencies by investing in the development of a high-quality steel recycling loop through its partner Gescrap.

Scope B assessment:

As metal recycling rates are already relatively high compared to other materials, closed loop recycling in the case of Gestamp will not lead to significantly higher circular outflow performance in scope B. However, the manufacturing waste produced by Gestamp form a uniform and high-quality feedstock for Gescrap in compared with scrap metals collected from other sources, allowing Gescrap to produce higher quality secondary materials. Through the collaboration between Gestamp, Gescrap, and their value chain partners, these high-quality secondary materials are returned to Gestamp allowing it to increase the recycled content of its products without loss of quality. This results in a larger circular inflow in Scope B.

Scope C assessment:

Another benefit of the closed loop recycling value chain that Gestamp and Gescrap have initiated, is that the steel producer consumes less resources to produce high quality steel. This is twofold:

- Less energy: Producing steel from scrap requires less energy than from iron ore. For the Scope C assessment of Gestamp, which has a similar scope as scope 3 assessments of GHG emissions, this would translate to less CO_2 emissions in the value chain.
- Less upstream waste: Secondly, the increased share of recycled content of Gestamp's products leads to less waste generation of especially mining activities upstream in the value chain.

Similar to the Signify case, just Scope B isn't sufficient to highlight the potential of reduced resource consumption of Gestamp's initiative in the automotive value chain.

JLR: Repurposing EV batteries

The energy transition requires a vast quantity of resources, mined from both urban and conventional mines, to be transformed into solar panels, wind turbines, electric vehicle (EV) batteries, and other infrastructure. Introducing the circular economy in parallel to this transition will be essential to make sure sufficient resources are available, both in the long and short term, and to minimize the quantity of required resources and related impacts. Automotive manufacturer JLR, known from the brands Jaguar, Range Rover, Defender and Discovery, is part of both transitions by developing EVs but also by exploring how EV components, such as the EV batteries that contain many CRMs, can be as productive as possible over multiple use cycles. For this case study, we have looked at the potential of repurposing I-PACE EV batteries into a Battery Energy Storage System (BESS) that helps stabilize the electricity grid.

Scope B assessment:

Assuming that JLR would take back EV batteries from cars it has sold in the past to repurpose them into a BESS, this will lead to an additional circular inflow into the company (in addition to the resources that it will still procure to develop new EV Batteries). In other words: the share of circular inflow will go up. As EV batteries already have high recycling rates at end-of-life, it does not result in higher circular outflows in scope B. To capture the fact that JLR has introduced a more high-value application for used EV batteries compared to recycling, we applied the metric Resource Productivity in our Scope B assessment. Resource Productivity shows the amount of revenue that is earned per kg of virgin resources consumed. As expected, we can see resource productivity go up if EV batteries have multiple use phases.

Scope D assessment:

Although the Scope B assessment already showed that the repurposing of EV batteries in energy systems increases both material circularity and resource productivity, there is another benefit that isn't captured in this scope: the fact that we have avoided the production of a new BESS. As the energy transition requires more capacity to stabilize the electricity grid due to the fluctuations in renewable energy production, we assumed that a BESS (or similar solution) from new batteries would be developed if JLR would not supply EV batteries for repurposing. This means that JLR can help avoid resource consumption in another value chain, which is only shown in a scope D assessment that includes the value chain of conventional BESSs, as we have done in our case study.

Hempel: High performance coatings

Although companies should always be incentivized to address the impacts of the resource flows within their direct control, this is not always where the biggest positive impact of a company can be made. The case study performed with paint- and coating-producer Hempel specifically focussed on the fact that their products, as many products from the chemical industry, are a relatively small part of the final products and assets they are applied to but can have a big impact on their quality and performance. In the case of Hempel, we explored the potential impact of a high-performance coating that outperforms other alternatives by making the assets it is applied to last longer. This will limit the number of resources required for maintenance and replacements of assets that have reached end-of-life.

Scope B assessment:

In the case of Hempel's high-performance coating, we assumed that this coating required an additional amount of resources in its production versus low-performance alternatives, for instance additional raw materials or energy. We assume that these additional resources are not particularly more or less circular than those used for the alternatives by competitors. Therefore, limited changes in the circular inflow or outflow of Hempel in Scope B is expected. However, the additional resources consumed would lead to a higher resource footprint and a lower productivity. In other words: a scope B assessment would lead to the conclusion that this particular high-performance coating is less circular than its alternatives.

Scope D assessment:

The key assumption that we've made for this case study, is that a high-performance coating produced by Hempel would extend lifetime of the asset it has been applied to. For most –if not all- assets that coatings are applied to, the coating will only represent a small part of the asset. If we include the value chain of such an asset in a Scope D assessment, this will show that even a small increase in the asset lifetime will help avoid resource consumption that easily compensates for the increased amount of resources of the high-performance coating. So, even though a Scope B assessment would show that the coating is less circular than its alternatives, a Scope D assessment would show that it is still making a much larger contribution to the transition to a circular economy.

Unlocking Circular Opportunities

Applying the Circular Economy Boundary Framework in the four case studies shows multiple ways for businesses to track and report their circular economy performance and the impact of the material flows that the company controls or influences.

Measuring the circularity of direct in- and outflows in Scope B is often not enough to determine the full impact of a circular solution.
Recent regulations have moved companies to focus on measuring and reporting the share of their circular inflows and outflows (i.e. in Scope B). However, our case studies show the limitations of that approach. Products or materials that are already largely or fully recycled (like batteries or scrap metal) will have no or a limited increase in circularity percentage when they are repurposed or upcycled in a closed loop, as is the case for Gestamp. Hence the value of these circular solutions needs to be shown via other metrics (like material productivity, GHG emissions) or in other scopes (like Scope D avoided material use in other value chains). In certain cases, a focus on only direct inflows or outflows might actually lead to circular solutions being penalised. For instance high-quality products that have significant positive effects beyond their own value chain, but might require some more resources, as shown in the Hempel case.

> "Contributing to this project has helped us to understand where and how boundaries need to be set in order to account for both positive and negative impacts across the full value chain. Having a clear and universal alignment on these boundaries will be critical as we look to scale up implementation towards a circular economy."
>
> **Alison Nuttall** - Head of Sustainability Global Affairs, JLR

Resource use reduction is mainly visible in Scope C and less in Scope B.
As a lot of the (hidden) material use lies upstream in the supply chain, switching from linear to circular inflows into the company does not necessarily reduce materials (in Scope B) by a significant amount. For companies with large supply chains, it will be recommendable to expand the analysis from Scope B to Scope C and take into account all materials consumed in the value chain, as this will show a much more complete picture of reduced resource use for most companies. This was very clear in the case studies of JLR and Signify, where the benefits of their circular economy solutions only became fully clear in Scope C.

Decoupling of resource consumption from economic activity is measured differently across the scopes.
For scopes A, B and C, resource decoupling this will result in reduced inflows and outflows measured over time. This was very clear from the Signify case study, where resource decoupling occurred over time in both Scopes B and C. For Scope D this will be an estimation of avoided resources in other value chains, comparing a business-as-usual scenario with a circular scenario (caused by the company's activities). This was demonstrated in the case of Hempel, where we showed how to estimate resource decoupling in scope D.

Embrace the Future of Business

As the urgency for sustainable resource management intensifies, it becomes increasingly clear that effective boundary setting is pivotal to understand critical resources flows and their impact. With the Circular Economy Boundary Framework Deloitte and Circle Economy Consulting aim to support organisations in navigating the complexities of circularity measurement, and report on the resource boundaries that make sense.

> "Circularity is a key topic for many years at Signify, we are interested to explore how this circular economy boundary framework can provide further insights beyond our own activities."
>
> **Thomas Marinelli** - Head of Sustainable Innovation and Design, Signify

The draft CEBF provides an additional methodology to delineate the various scopes of resource flows, and providing a useful input for businesses when considering how to define their boundaries as part of wider circular economy measurement activities. Applying clear circular economy boundaries can help companies to achieve the following:

01. **Enhanced Visibility and Accountability**: The clear delineation of scopes allows businesses to identify their direct and indirect impacts more effectively. This increased visibility fosters accountability and encourages organisations to incorporate circular economy initiatives.
02. **Improved Decision-Making**: Equipped with a better understanding of their material flows, organisations can make more informed decisions regarding resource procurement, product development, and waste management strategies. This will help businesses to prioritise circular solutions that enhance sustainability without compromising profitability.
03. **Catalyst for Innovation**: The insights from the CEBF can be used for companies to rethink their traditional business models and explore innovative solutions that drive the transition to a circular economy, from improvements in their own operations to the wider impact that have in and beyond their value chains. This emphasis on creativity can lead to the development of new products and services that contribute to a circular economy.
04. **Benchmarking and Comparison**: The standardised approach of the CEBF enables organisations to perform analyses that lead to comparable results across businesses, allowing them to benchmark their circular economy performance against industry peers. This capability is vital for establishing best practices, sharing insights, and fostering a collaborative environment for circularity improvement across sectors.
05. **Regulatory Compliance and Risk Mitigation**: By understanding their operational boundaries, businesses can better navigate regulatory requirements and mitigate risks related to resource consumption and waste disposal. This proactive approach can result in cost savings and enhanced corporate reputation.

We recognize that the draft CEBF is not finished and further development is needed. We invite industry leaders, sustainability professionals, investors, and policymakers to engage in meaningful discussions on circular economy boundaries. The path to circularity begins with clear boundaries—let us set them together.

Case study fact sheets

Signify: Light-as-a-service

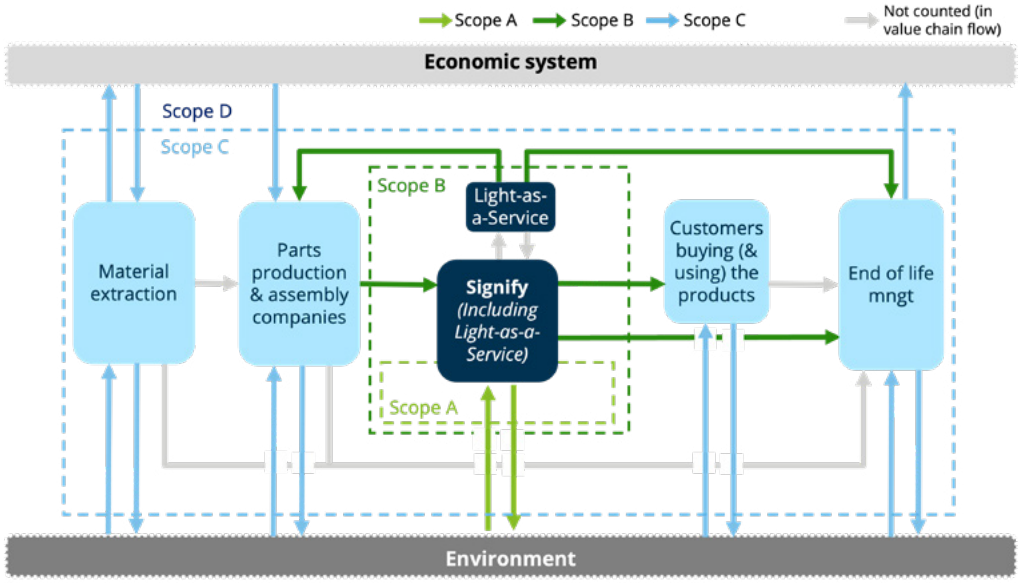
Key material flows

	Upstream	Downstream
A	Scope A material flows are minimal for Signify and not considered in the case study.	
B	**Inflow**: Procured materials and parts, that Signify uses in the production of their luminaires	**Outflow**: Lamps and luminaires exiting Signify's system after being rented or sold, as well as waste generated by Signify
C	**Inflow**: Materials used and extracted upstream in the value chain to produce Signify's lamps and luminaires **Outflow**: Waste generated upstream	**Outflow**: Luminaires at end-of-life and waste generated during the use phase of the luminaires
D	In this case study no material Scope D flows are identified.	

The potential of switching from a linear to a circular as-a-service model

Product-as-a-service is a business model in which products are not sold to customers but are provided to them as part of a service or subscription. Signify's Light-as-a-Service (Laas) model allows customers to pay for the light, not lighting, that they use. This allows Signify to benefit from more durable and high-quality products, which will require less replacements.

Signify's Light-as-a-Service simplified value chain



Case study fact sheets (Cont')

Signify: Light-as-a-service

Key assumptions

To understand the impact of Light-as-a-Service (LaaS), we compare the baseline scenario of only linear sales, with a hypothetical scenario of 50% LaaS after 20 years:

Scenario 1 - Linear sales

- Product sales is 100% linear.
- Around 25% of the resource inflow consists of secondary materials (e.g., recycled metals).
- At the end of the use phase, luminaires are not returned to Signify, but amongst others collected via Collective Recycling Organisations.
- End-of-life material recovery (recycling) rate is 50%.

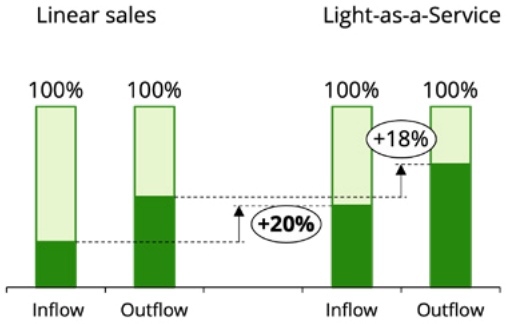
Scenario 2 - Light-as-a-Service

- 50% of the sales is linear and 50% is LaaS.
- After 20 years the LaaS model is mature and there a steady supply of returned products, of which
  - 33% is reused again in a LaaS contract.
  - 67% is sent to partners for remanufacturing, refurbishment or recycling resulting in an 80% recovery rate
- 75% of inflows for new LaaS products come from remanufactured or refurbished components, or recycled materials

The potential of switching from a linear to a circular as-a-service model

Key insights on circularity scopes

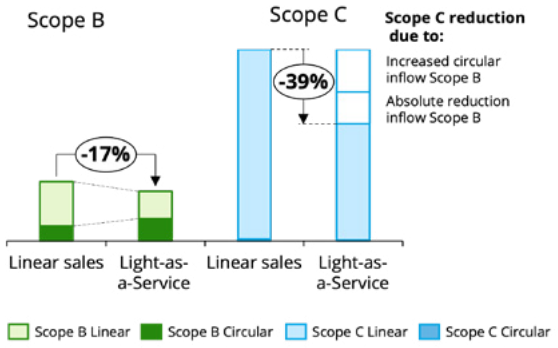
1. Circularity of scope B flows (%)



Key insights

- Both the circularity of Scope B inflow and outflow increases due to more control and higher recovery rates and use of secondary materials and remanufactured or refurbished components

2. Resource use (kg)



Key insights

- Returned luminaires which are reused reduce Scope B inflow, and consequently also Scope C inflow.
- Note that returned and reused luminaires are not considered Scope B inflow as they remain within Signify's ownership.
- Due to the increased circular scope B inflow, Scope C flows are also reduced, especially reduced resource extraction and waste upstream.

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Case study fact sheets (Cont')

Gestamp: Closed loop recycling of manufacturing waste

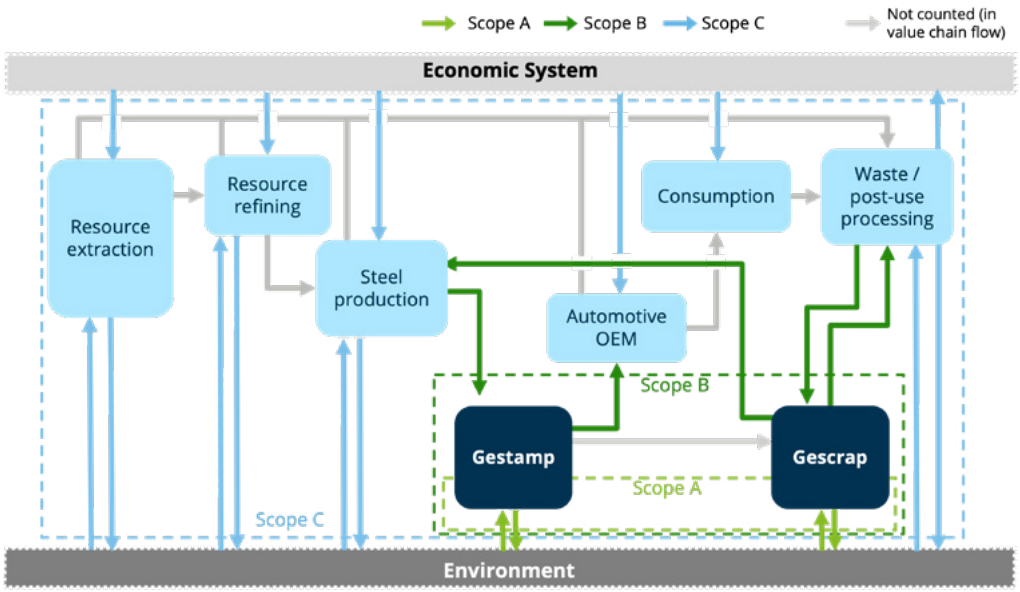
Key material flows

	Upstream	Downstream
A	Scope A material flows are minimal for Gestamp and Gescrap and not considered in the case study.	
B	**Inflow** *(Gestamp)*: Procured materials and parts, such as steel coils **Inflow** *(Gestamp)*: Procured materials and parts, such as steel coils	**Outflow** *(Gestamp)*: Finished automotive parts delivered to OEMs as well as manufacturing waste
C	**Inflow**: Raw materials extracted through mining **Outflow**: Waste and emissions from mining and steel processing	**Outflow**: Waste and emissions generated during the car use or end-of-life management
D	In this case study no material Scope D flows are identified.	

The potential of switching from a linear to a high-quality recycling model

Gestamp contributes to developing a high-quality steel recycling loop of pre-consumer industrial waste, by investing in scrap recycling. This increases the circular inflows of the automotive value chain and reduces CO_2 emissions and resource use upstream.

Gestamp and Gescrap's closed loop recycling simplified value chain



Case study fact sheets (Cont')

Gestamp: Closed loop recycling of manufacturing waste

Key assumptions

To understand the impact of closed-loop recycling on Gestamp's operations, we compare two scenarios:

Scenario 1- Baseline: Gestamp and Gescrap are separate entities.

- Gestamp sources steel with a recycled input rate of 16%. The automotive industry requires a high steel grade, hence Gestamp's steel producer cannot increase the recycled content, due to the mixed quality of secondary materials they receive.
- Gestamp's pre-consumer waste is sent to recycling but not received back as part of a closed loop.

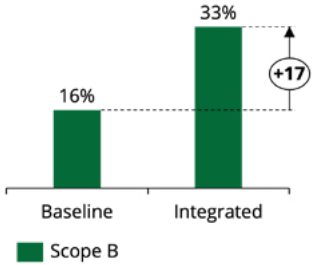
Scenario 2 – Integrated: Gestamp and Gescrap are combined entities.

- Gescrap works with Gestamp to have a closed recycling loop:
  - Gestamp generates pre-consumer metal waste and send it to Gescrap (~1/3 of Gestamp's procured steel volume become waste).
  - Gescrap processes the scrap and sends high quality steel scrap to the steel producer.
- Due to the materials quality and volume, the steel producer can increase recycled content to 33% in the steel sheets sold to Gestamp.
- Gescrap's resource use, circularity of flows, waste and emissions are assumed to remain the same.

The potential of switching from a linear to a high-quality recycling model

Key insights on circularity scopes

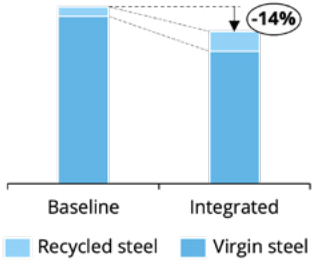
1. Circularity of Scope B inflows: % of recycled content



Key insights

- As part of a closed loop, Gestamp's circular inflow can increase from 16% to 33%. This is driven by the direct recapture of higher grade and volumes of pre-consumer scrap from Gestamp's operations.

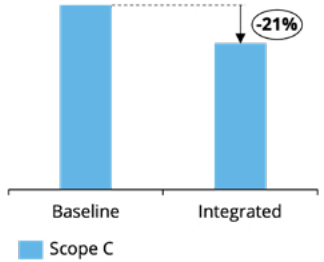
2. Scope C – CO_2 emissions[1]



Key insights

- CO_2 emissions are reduced for Gestamp's procured steel due to use of higher amount of high-quality recycled vs virgin steel.
- These are Scope C reductions and correspond with GHG Scope 3 reductions for Gestamp as material purchaser.

2. Scope C – Resource use



Key insights

- In addition to reduced GHG emissions from steel production, further upstream resource use and waste from mining is also reduced as less extraction of primary steel is needed for Gestamp's activities.

[1] An emission factor of 2.32 tCO_2 per tonne of steel is assumed for virgin steel, vs 0.70 tCO_2 per tonne is assumed for recycled steel Disclaimer: The graphical representations and underlying data and assumptions included in the case studies are for illustrative purposes only and may not reflect reality or necessarily based on available commercial models.

Case study fact sheets (Cont')

JLR: Repurposing EV batteries

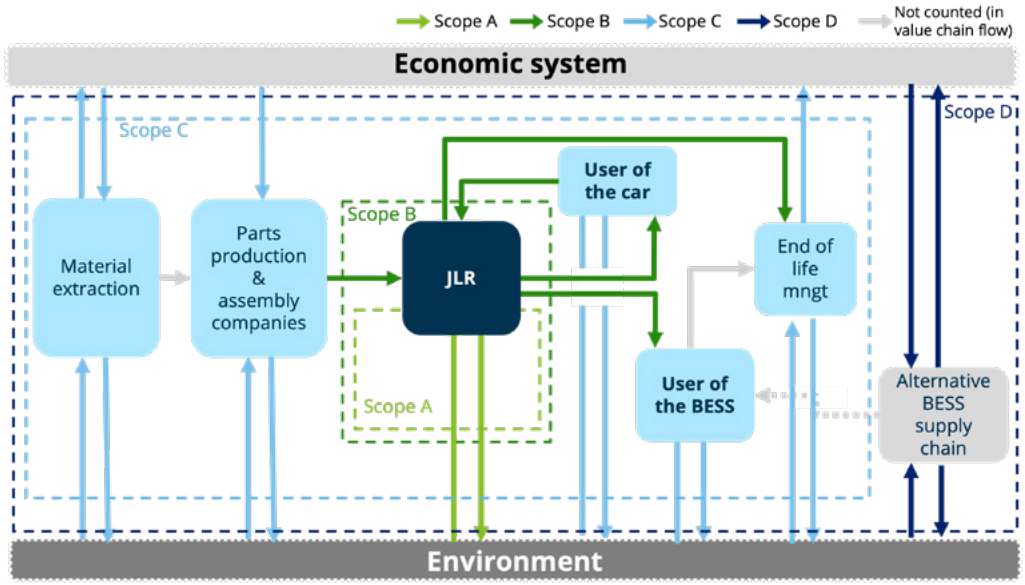
Key material flows

	Upstream	Downstream
A	Scope A material flows are minimal for JLR. This scope includes possible (GHG) emissions related to JLR's validation of battery cells at the UK Battery Industrialisation Centre. Scope A is not considered in the case study.	
B	**Inflow**: Procured battery-cells from suppliers	**Outflow**: EV-batteries and BESS sold and shipped to users
	Inflow: Used EV-batteries returned to JLR by consumers	
C	**Inflow**: Materials used and extracted upstream in the value chain, including critical raw materials like lithium, cobalt, and nickel **Outflow**: Mining waste	**Outflow**: Batteries processed at end-of-life
D	Materials used and waste & emissions generated in the alternative BESS value chain.	

The potential of switching from a linear to a re-use model

JLR increases its resource efficiency by employing second-life Jaguar I-PACE batteries in a Battery Energy Storage System (BESS). After first use the I-PACE battery is returned to JLR. The battery is checked and repurposed in a BESS. This expands the battery life-cycle and increases material productivity. In addition, the BESS users don't need to purchase an energy storage system made from virgin materials, this results in avoided material use in the alternative BESS value chain.

JLR's repurposed I-PACE battery simplified value chain



Case study fact sheets (Cont')

JLR: Repurposing EV batteries

Key assumptions

To understand the impact of repurposing batteries, we compare the baseline scenario for EV batteries with a hypothetical repurposing scenario:

Scenario 1 - EV battery with single use

- The battery is used for 8 years in an EV and not reused.
- Around 10% of the resources for new batteries consists of secondary materials (e.g., recycled metals).
- At the end of its use phase, EV battery is sent for recycling.
- End-of-life material recovery (recycling) rate is 95%.

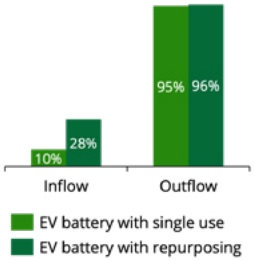
Scenario 2 - EV battery with repurposing

- After first use, one in four EV batteries are repurposed in a Battery Energy Storage System (BESS). For every 4 EV-batteries sold, per year, 1 BESS is sold.
  - Battery lifetime increases from 8[1] years to 16 years.
  - Number of battery cycles increases, and the total resources used per cycle reduces.
  - 1 JLR BESS, replaces a similar[2] BESS in an alternative value chain.
- There is no change in circular inflow (10%) for new batteries while inflow of pre-used batteries is considered 100% circular.

The potential of switching from a linear to a re-use model

Key insights on circularity scopes

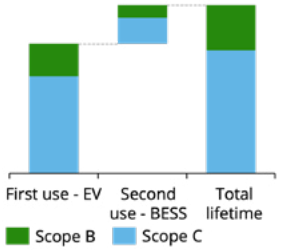
1. Circularity of scope B flows



Key insights

- There is no change in circular inflow (10%) for new batteries.
- As 1 in 4 EV batteries is reused, in the mix Scope B circular inflow increases to 28%.
- Similarly, outflow increases slightly from 95% (recycling only) to 96% (recycling + reuse).

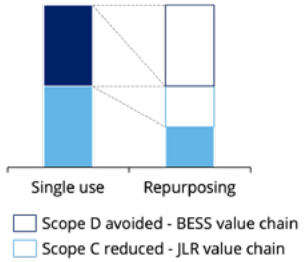
2. Material productivity (euro/kg)



Key insights

- Revenue for repurposed batteries increases at first sale for an EV, at second sale for a BESS.
- Resource productivity (EUR/kg) increases for both JLR in- and outflows (Scope B) and JLR's value chain (Scope C).

2. Resource use per year per repurposed battery



Key insights

- Material consumption per year is reduced in both value chains.
  - Note this does not reduce the total materials used for one battery.
- In Scope C (JLR's value chain), doubling of the battery lifetime halves the material used per year in kg.
- In Scope D, resource use is avoided in the alternative BESS value chain.

[1] based on current I-Pace battery warranty; 2 similar in weight, capacity, performance, and duration
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Case study fact sheets (Cont')

Hempel – High performance coatings

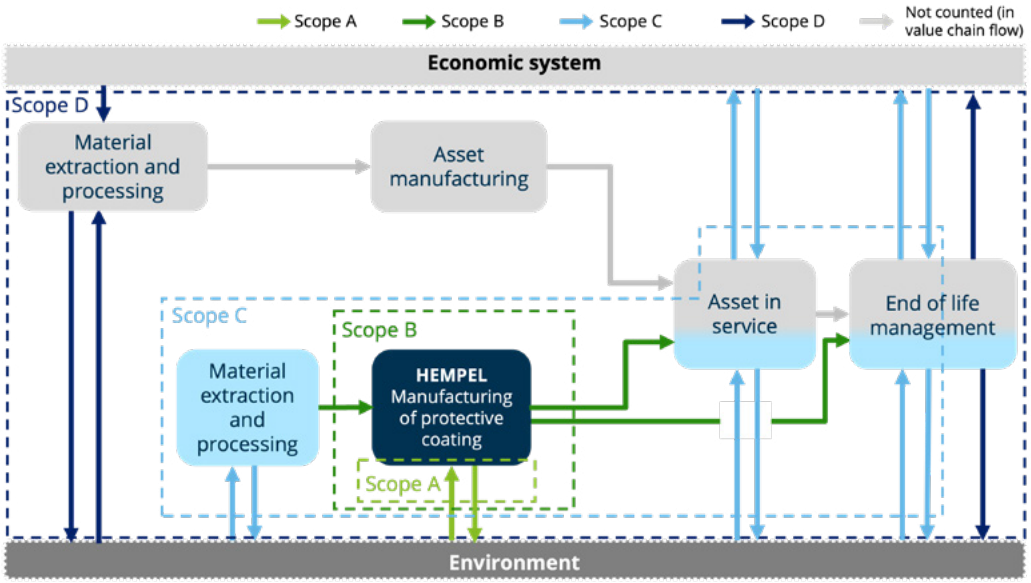
Key material flows

	Upstream	Downstream
A	Scope A material flows are minimal for Hempel. This scope includes possible (GHG) emissions related to logistics for Hempel.	
B	**Inflow**: Raw materials, such as resins, procured from suppliers.	**Outflow**: Products, such as paints and coatings, sold to customers and manufacturing waste.
C	**Inflow**: Materials used and extracted upstream in the value chain, for resin production **Outflow**: Materials wasted for resin production.	**Inflow**: Materials used for application and use of paints (for instance, application tools such as brushes, rollers and spray guns) **Outflow**: Materials wasted for application and use of paints; end-of-life management of paints, and manufacturing waste
D	Materials such as steel and cement, used for the construction and/or maintenance of painted/coated assets.	

The potential of providing a high-quality protective coating that extends the lifetime of an asset

Protective coatings increase durability of assets by providing corrosion protection and hence, reduce the need for (for example) metal used in production of new assets and in the maintenance.

Hempel's protective coating simplified value chain



Case study fact sheets (Cont')

Hempel – High performance coatings

Key assumptions

To understand the impact of the protective coating, we compare 2 different coatings (A and B) with different performances. For both products:

- No secondary materials are used in coating manufacturing.
- The compositions are largely similar, and so is the manufacturing process.
- There is no recovery of coating at the end-of-life.

Product A – Lower quality:

- It has lower durability and provides only basic protection.

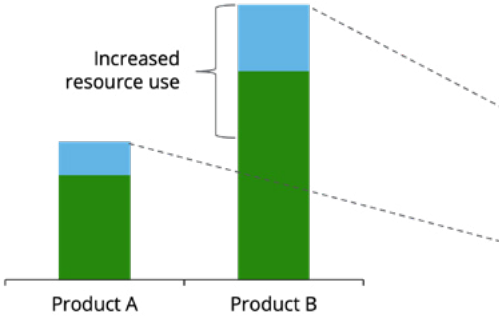
Product B – Higher quality:

- It has higher durability and provides superior protection.
- As it has a higher quality compared to product A, it consumes more resources during its production.
- The lifetime and durability of the asset that the coating is applied increases.

The potential of providing a high-quality protective coating that extends the lifetime of an asset

Key insights on circularity scopes

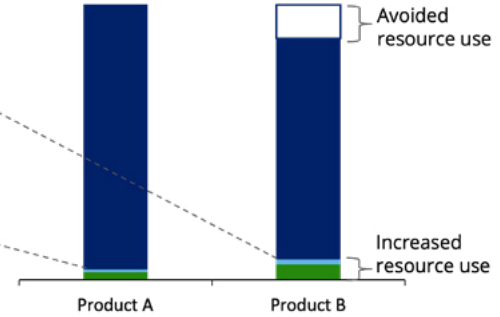
1. Scope B & C Resource consumption



Key insights

- Resource consumption in both Scope B & C increases.
- Product B is less resource efficient.

2. Scope D Resource consumption



Key insights

- Even with a small increase in the lifetime of the asset, the avoided resource consumption in Scope D for Product B is significantly larger than the increased resource consumption in scopes B and C.
- Although a Scope B assessment shows that Product B is less resource-efficient, its increased resource efficiency in Scope D highlights its greater contribution to the transition to a circular economy.

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Acknowledgments

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Lead authors:
Dieuwertje Ewalts (Deloitte Netherlands) & Jacco Jochemsen (Circle Economy Consulting)

Contributing authors:
Deloitte Netherlands: Lian van Rooij
Deloitte Spain: Cecilia Dall Acqua, Sofia Ines Pellarin
Circle Economy Consulting: Gamze Ünlü, Philip Sin

Contributors case studies
Signify: Thomas Marinelli
Gestamp: Ander Urrutia Mendez, Beatriz Alonso Wehrli, Ernesto Barcelo Rodriguez, Ines Rodriguez Pariza
JLR: Alison Nuttall, Claire O'Connor, Fabian Watelet, Peter Chigada, Vimasha Jeewandara
Hempel: Pau Huguet, Yorgos Chalkias

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