ADVANCING THE CIRCULAR ECONOMY: BUSINESS AND FINANCE PERSPECTIVES

Insights and evidence from the NICER Programme

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CE-HUB
UKRI National Interdisciplinary Circular Economy Research

NICER PROGRAMME

University of Exeter

UK Research and Innovation

Contents

Abbreviations

Term	Abbreviation
Business ecosystem	BE
Circular Business Model	CBM
Circular Economy	CE
Manufactured Carbonaceous Materials	MCMs
Product-as-a-Service	PaaS
Product Service System	PSS
The Interdisciplinary Centre for Circular Metals	CircularMetal
The Interdisciplinary Circular Economy Centre for Mineral-based Construction Materials	ICEC-MCM
The Interdisciplinary Circular Economy Centre for Technology Metals	Met4Tech
The Interdisciplinary Centre for the Circular Chemical Economy	CircularChem
The Textiles Circularity Centre	TCC

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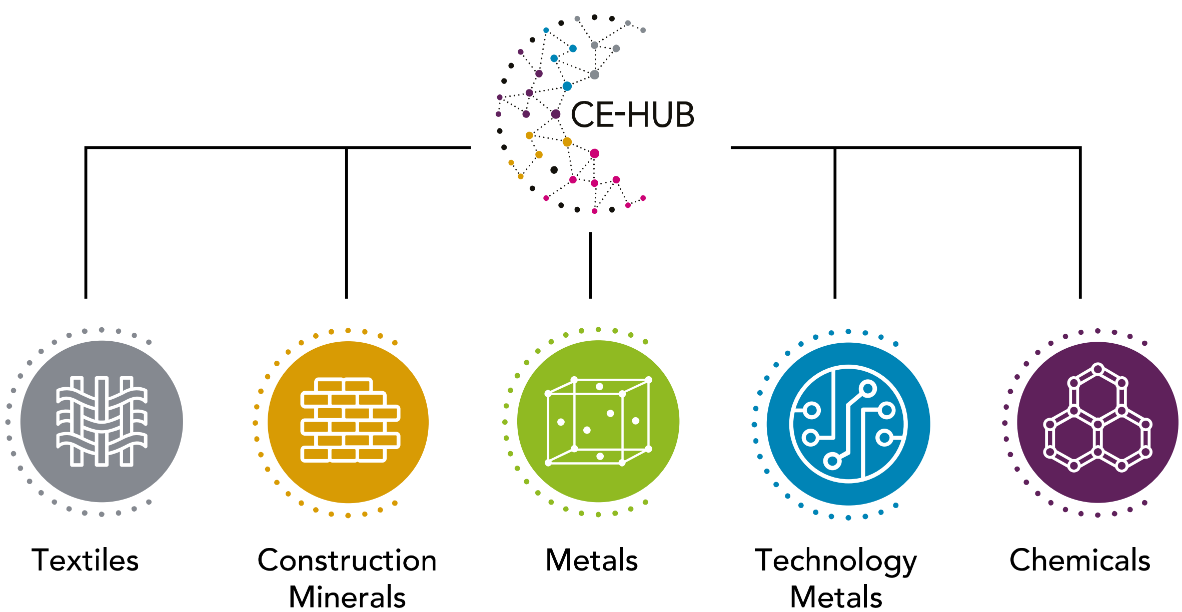
About the Interdisciplinary Circular Economy Research Programme

The National Interdisciplinary Circular Economy Research (NICER) programme is a £30 million four-year investment from UKRI and the Department for Environment, Food & Rural Affairs (DEFRA) to deliver the research, innovation and evidence base needed to move the UK towards a circular economy. Launched in January 2021 and comprising initially of 34 universities and over 150 industrial partners, NICER is made up of five Circular Economy Research Centres each focused on a specialty material flow, and the coordinating CE-Hub:

- The National Interdisciplinary Circular Economy Research Hub (CE-Hub), led by the University of Exeter
- The Textiles Circularity Centre (TCC), led by the Royal College of Art
- The Interdisciplinary Circular Economy Centre for Mineral-based Construction Materials (ICEC-MCM), led by University College London
- The Interdisciplinary Centre for the Circular Chemical Economy (CircularChem), led by the University of Surrey
- The Interdisciplinary Circular Economy Centre for Technology Metals (Met4Tech), led by the University of Exeter
- The Interdisciplinary Centre for Circular Metals (CircularMetal), led by Brunel University London

NICER is the largest and most comprehensive research investment in the UK Circular Economy to date. It has been delivered in partnership with industrial organisations from across sectors and DEFRA to ensure research outcomes contribute to the delivery of industrial implementation and government policy. A core aim of the programme is growing the Circular Economy community through a significant programme of outreach and collaboration.



About the NICER Insight Reports series

The objectives of the NICER programme are to:

1. Accelerate understanding and solutions to enable circularity of specific resource flows,
2. Provide national leadership, coordinate and drive knowledge exchange across the programme as a whole and with policy, consumer, third sector and business stakeholders,
3. Ensure research is embedded with stakeholders by involving businesses, policymakers, consumers and society, the third sector, and other affected groups and communities at every part of the programme.

The transition towards a UK circular economy requires a whole system approach. This means that, in addition to accelerating knowledge at the resource and sector level, there are a number of agnostic system level enablers or drivers that can be applied to accelerate adoption at scale. The purpose of the NICER Insight Report Series is therefore to highlight learning from across the NICER Programme in relation to these system wide enablers.

Advancing the Circular Economy: Business and Finance Perspectives

An Overview

Transitioning to a circular economy (CE) requires companies to adopt circular business models (CBMs) that generate, capture, and deliver values in ways that are both sustainable and economically viable. CBMs serve as frameworks for securing essential funding for sustainability efforts by aligning business operations with CE principles: refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover (9Rs).

While progress has been made in advancing CE practices in the UK, there is a need to increase the pace of the transition towards increased circularity. Achieving effective implementation of CBMs requires a systems approach supported by enabling mechanisms, rules and regulations, and other enablers that foster the development of circular business ecosystems. This report examines the CE transition through the dual perspectives of business models and finance, leveraging insights from the **CE Hub** and five specialised CE research centres focused on **Textiles, Chemicals, Construction Minerals, Metals,** and **Technology Metals**.

Over five sections, we present actionable insights and practical recommendations to guide businesses reconfiguring their business models to accelerate their transition to a CE. Additionally, we outline funding options and requirements at different stages of the CE journey.

Below, we summarise ten key insights gained through the NICER Programme:

1. **Foster a shared understanding of the big picture and enable proactive management:** Circularity does not happen in isolation but emerges through proactive collaborations among diverse stakeholders. To effectively advance circular practices, all participants need to develop a clear understanding of the broader ecosystem and their role within it.
2. **Integrate CE principles into business strategies and culture:** Align goals with internal and external environments to enable the customisation and adaptation of business models.
3. **Ensure economic benefits for all partners:** Partners in the ecosystem should gain economic rewards and strategic advantages, both in the short and long term.
4. **Share value and risks equitably:** For a self-sustaining circular ecosystem, value and risks must be balanced among partners fairly.
5. **Building internal and external networks:** Facilitate collaborations for value co-creation, cascading resources, and waste minimisation, employing several approaches such as supply chain integration and industry symbiosis to maximise collective gains.
6. **Leverage technologies:** Harness technologies to enhance resource efficiency, minimise waste, and extend product lifecycles, driving more sustainable operations and outcomes.
7. **Diversify funding sources and strengthen financial resilience:** Optimise capital structures, capitalise on internal resources, and seek diverse funding sources to effectively pursue circularity objectives.
8. **Tailor financing mechanisms:** Develop stage-specific financial solutions to support technological innovation at each investment phase to support CBMs.
9. **Utilise both strategic and financial investors effectively:** Optimise financial and non-financial supports from strategic and financial investors throughout different phases of the technological innovation.
10. **Educate consumers:** Build demand for CE products through education and consumer engagement initiatives such as information campaigns, workshops, and product labelling.

1. The Conceptual Circular Business Models (CBMs)

CBMs often operate within complex systems comprising multiple interconnected business ecosystems (BEs). These ecosystems bring together diverse actors who collaborate, co-evolve and co-create value, while also requiring closed loop designs to minimize wastes. Success in CBMs requires aligning the goals, rules, and mindsets of all stakeholders towards circularity (Sudusinghe and Seuring, 2022). This paradigm shift involves a systematic transformation of resources and information flows throughout the entire value chain.

This report adopts Osterwalder and Pigneur's (2010) business model canvas to conceptualise a CBM since this framework is widely recognised for its robust academic foundation and frequent application by practitioners in business model developments. To enhance its utility for circularity, we integrate nine CE principles (9Rs) into each element of the canvas. These principles, combined with the six aspects of a CE framework outlined in ISO59004 - systems thinking, value creation, value sharing, resource stewardship, resource traceability, and ecosystem resilience – distinguish traditional business models with CBMs. The proposed conceptual CBM provides a clear roadmap for firms to reorient their businesses practices towards circularity.

At the heart of a CBM lies the **circular value proposition**, which focuses on offering products/services designed with circularity at their core, emphasising sustainable value creation. This includes models like Product-as-a-Service (PaaS), which is also known as Product Service System (PSS), where consumers use products while the companies retain ownership. For example, MetalClean Solutions' performance-based leasing (UNIDO, 2024) is one such circular business model in the Metal industry, highlighting Metal Molecules as a Service (CircularMetal). Other examples include virtual products/services (Tukker, 2004), circular products created from waste and cascading materials down the waste hierarchy (e.g. categorising clothes into different grades for various treatments) (Rapsikevičienė, Gurauskienė, and Jučienė, 2019).

CBMs are increasingly focusing on developing diverse **revenue streams** to increase the economic viability of firms' CE initiatives. For instance, firms can leverage input-based revenue streams (offer resources/services rather than ownership), availability-based PSS (availability of a product/service), usage-based PSS (payment for the use of products/services), performance-based (performance-based contracting), solution-oriented (e.g., heat transfer efficiency promises instead of radiator sales), and effect-oriented (e.g., offering cooling services). Another critical revenue stream involves recovering value through the reuse, repair, remanufacture, refurbishment, repurposing, and recycling of products and materials (Van Ostaeyen et al., 2013). For instance, an interview with Sarah Hayes (Circularity Expert at H&M) revealed that integrating circularity at the design stage is key to enabling product reuse and recycling.

Circular businesses cater to **customer segments** that prioritise sustainable consumptions. These customers are increasingly mindful of the environmental impact of their purchasing decisions and seek products and services that are eco-friendly, reliable, and cost-effective. For example, consumers of subscription-based consumables often prefer environmentally friendly and affordable alternatives to traditional, single-use products for their daily needs. Therefore, a better understanding of customer behaviours towards circular products is critical to firms to determine their customer segments. The Textiles Circularity Centre (TCC) joined the Circular Fashion Experience at Brazil Eco Fashion Week 2023 to share their research on circular economy in the textile industry and to learn how customers interact with circular fashion products in Brazil.

In a CBM, **customer relationships** should be strengthened since consumers can actively participate in the value creation process. To reduce the overproduction of wastes, firms can adopt a "produce-on-order" approach, in which, products are manufactured based on customer orders. End-use customers can contribute to product design by providing feedback or participating in customer votes. The implementation of social marketing strategies further enhances this engagement by facilitating two-way communications between firms and customers, which encourages the greater participation in and adoption of CE practices (Govindan, Soleimani, and Kannan, 2015; Song et al., 2024). One such example is TCC's Compositor Tool which explores new experiential ways that consumers can participate in the circularity of the fashion industry.

Key activities are fundamental for creating, offering, and delivering value propositions within a CE. To promote resource efficiency, companies need to optimise their operations through a combination of activities such as improving process controls, utilising advanced technology, fostering knowledge sharing, embracing virtualisation and digitalisation, and modifying equipment (Systems thinking) (El-Haggar, 2007). A key focus lies in circular design, which ensures that materials at the end of a product's lifecycle can be easily recovered and repurposed as inputs for new cycles. Design efforts should prioritise reducing the use of virgin materials, minimising energy consumption and emissions, prolonging product lifespans, and eliminating waste through strategies such as design for disassembly.

In parallel, firms should proactively engage in advocating for regulatory and political incentives that accelerate the shift towards a CE (Sehnem et al., 2019). During the inaugural 2022 NICER Programme CE Showcase, an interview with Valentina Dipietro, founder of Mykor discussed nature-inspired design as a CE enabler. Likewise, Met4Tech proposed a roadmap for achieving a CE in lithium-ion batteries, highlighting the importance of design for recycling to facilitate easier cell disassembly (Harper, et al., 2023). ICEC-MCM introduced the design concept for de-constructing lightweight infill wall systems (Kitayama & Iuorio, 2022)

CE-based businesses strive to optimise the use of a variety of **key resources** to enhance their operational performance and sustainability. One effective strategy is circular sourcing, in which recovered resources from used products, such as worn-out components or wastes, are reintegrated into the supply chain, often through reverse logistics (resource stewardship). Beyond resource recovery, businesses can also utilise higher-performing materials that meet or exceed the technical requirements of traditional materials while being more sustainable and less harmful to the environment (El-Haggar, 2007). For example, multi-principal-element alloys and multicomponent high-entropy Cantor alloys, as studied by CircularMetal, are better performing materials. Furthermore, companies can digitalise their materials to enhance resource tracking (resource traceability) management that will boost overall operational efficiency (ecosystem resilience).

Circularity is often achieved through effective **collaborations** within cooperative networks that enable companies to share resources (value sharing) and optimise operations (systems thinking). The more diverse a firm's partnerships across its value chain, the greater its capacity to implement CE practices (Sudusinghe and Seuring, 2022). One notable example is industrial symbiosis, where waste or by-products of one company or industry become resources for another. Marques-McEwan et al., (2023) highlighted a successful case of industrial symbiosis between the steel and chemical industries, where collaboration allowed for the substitution of fossil-derived inputs with captured carbon.This not only prevented the release of carbon into the environment but also enhanced the circularity of the entire system.

Transitioning to a CBM requires leveraging novel **channels** to effectively deliver value propositions. For instance, in alignment with closed-loop operations, a take-back system can be established. This system, supported by reverse logistics, enables companies to collect used products for reuse, repair, remanufacture, refurbishment, repurpose, or recycling. Managing this system is essential to achieve cost efficiency, minimise environmental impact, and ensure customer satisfaction. However, one significant challenge lies in the availability and quality of feedstock. To mitigate potential disruptions, it is essential to establish multiple channels for securing high-quality feedstock, ensuring the smooth flow of materials and preventing interruptions in operations (Govindan, Soleimani, and Kannan, 2015).

Generating values and profit in a CE relies on developing diverse **revenue streams**, derived from traditional products, circular products, and wastes. These streams emerge through CE activities such as offering PSS, creating new revenue opportunities from waste by repairing, reusing, remanufacturing, refurbishing, repurposing products and parts, and recycling materials (Munaro and Tavares, 2023). To support these activities, businesses must adopt an appropriate **cost structure** aligned with the organisational changes required for a successful transition to a CE. This cost structure should be guided by evaluation criteria that assess the efficiency of CE policies and their optimisations. As revealed in the Circular Niobium project implemented by Met4Tech, the cost modelling results demonstrate a potential for economic recycling of niobium alongside other battery materials. Moreover, other key considerations include customer incentives for take back systems, cost savings from circular material flows, and the investments required to implement these changes (Subramanian and Gunasekaran, 2015).

While CBMs share fundamental elements and principles, there is a need to tailor them to meet the specific needs of individual firms and industries. This **customisation** depends on a company's internal characteristics/capabilities (e.g., organisational knowledge, culture, leadership, intangible assets, existing networks, and transition processes), and external drivers (e.g., political, economic, technological, legal, environmental and sociocultural factors). Both play a significant role in shaping how CE practices are adapted and implemented (Roos, 2014).

In summary, the conceptual CBM serves as a comprehensive framework that guides businesses through the transition to a CE. It encompasses various aspects of business operations while integrating CE principles, supported by six foundational pillars – systems thinking, value creation, value sharing, resource stewardship, resource traceability and ecosystem resilience (ISO59004).

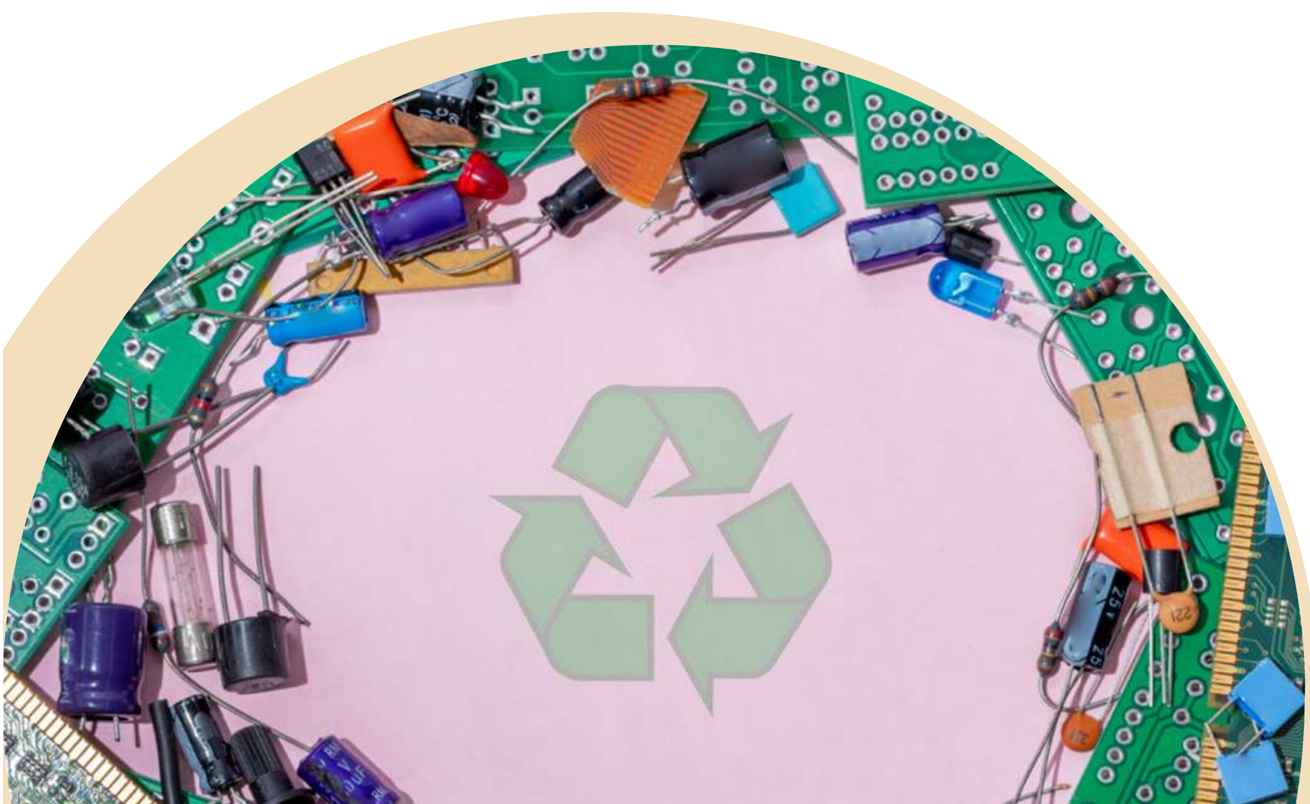


Table 1. Examples from NICER Programme illustrating different aspects of the conceptual CBM

No	Example/Case study from NICER Programme	Contribution
1	Metal Molecules as a Service by CircularMetal.	This demonstrates circular value proposition.
2	An interview with Sarah Hayes (Circularity expert at H&M) by CE Hub.	The interview revealed the importance of the textile product development process towards circularity.
3	TCC's Consumer Experience research strand in Brazil.	This research enabled learning about customer behaviours towards circularity.
4	The Compositor Tool by TCC.	This tool, based on the application of technologies, facilitates engagement with customers in the circularity of materials.
5	The inaugural NICER Programme CE Showcase.	This interview stimulated nature-inspired design.
6	A roadmap for achieving a CE in lithium-ion batteries by Met4Tech.	This roadmap emphasized the importance of design for recycling to facilitate easier cell disassembly.
7	ICEC-MCM's design concept for de-constructing lightweight infill wall systems.	This concept demonstrates circular product design.
8	Multicomponent high-entropy Cantor alloys studied by CircularMetal.	These materials are examples of higher performing materials.
9	BASF's ChemCycling™ project has built a collaborative network of partners to capture and chemically recycle different waste streams, including mixed plastics, into virgin-grade products.	This highlights the role of collaborations in a CE.
10	Circular Niobium project implemented by Met4Tech.	The cost modelling outcomes demonstrate the importance of economic evaluations of a CE practice to make suitable decisions.

2. CBM Strategies: Proactive Practices

The dynamic nature of CBMs implementation reflects the diverse strategies that firms can adopt when transitioning to a CE. From a transition perspective, start-ups have the advantage of embedding CE practices directly into their core operations from their inception. In contrast, established firms often face challenges in moving away from traditional linear models, which may require significant restructuring and operational shifts. To navigate this transition, businesses can pursue several strategies: developing new circular business units within their current structure, acquiring and integrating external circular business units, or adopting a hybrid approach that preserves their traditional operations while incorporating circularity (Geissdoerfer et al., 2018). These strategies allow businesses to select the path that best aligns with their institutional environment, market conditions, and business goals.

Firms also adopt a range of CE strategies based on operational approaches structured by the hierarchical ladder, which classifies CE activities into distinct groups according to varying levels of product functionality and/or operational processes (Potting et al. 2018, Moraga, et al., 2019). These strategies encompass six major approaches that emphasise the preservation of products, supported by such concepts as PSS, the sharing economy, virtualised products and/or services, whilst being grounded in the 9R CE principles (Moraga, et al., 2019). Each strategy exhibits unique characteristics, delivery methods, strengths and weaknesses that firms need to evaluate in the context of their internal and external environment.

The circular product model is underlined by the service delivery mode, in which, products are designed as PSS and visualised as much as possible (value creation and resource stewardship). Prominent examples include Tesla's leasing program, BMW and Daimler's shared vehicles, and CastLab's on-demand metal casting model, all of which have adopted the PSS concept. This model allows products to be continuously maintained and updated, thereby extending their lifespan naturally. As a result, firms can generate higher revenue while offering flexible and affordable services to customers. However, this model presents challenges for circular businesses, as customers can easily switch to other PSS and its operations may be exposed to several types of risk, such as a shortage of funds due to the highly leveraged business model, vulnerability to recession, and long payback periods, amongst others.

The product life extension model focuses on prolonging the life of products by implementing reuse, repair, remanufacture, refurbish, repurpose, and recycle principles (value creation and resource Stewardship). For example, Pangaia, a textile company, promotes the concept of "rewear" (Pangaia, 2024); emerging technologies like self-healing metals could revolutionise the metal industry. This model not only increases revenue streams while utilising resources more efficiently but also fosters high customer retention rates due to strong collaborations with customers through take-back systems. However, adopting this model involves significant upfront investment costs, complex operational management, and substantial efforts in customer education and engagement, as it requires a radical transformation of the entire operational system towards CE principles.

The circular inputs model, which transforms parts of products into valuable new products or materials, plays a key crucial role in minimising waste and reducing input costs (resource stewardship). Notable examples include Caterpillar's remanufacturing of diesel engines and GreenPower Solutions' refurbishment of electric vehicle batteries for energy storage (CircularMetal's study). While this model enhances relationships between firms and with their customers, as customers are actively involved in the product collection process, the significant initial investment in technologies (e.g., systems for treating used products/materials) can make this approach costly, and firms need to invest in customer education and relationship management to ensure the efficient collection of product parts.

The resource recovery model focuses on recovering materials and/or minimising waste (ecosystem resilience). For instance, metal scraps can be recycled to reduce landfill use, while wood from demolished buildings can undergo cascading treatment for reuse in new building components, furniture, or wood products (value sharing). By transforming waste into valuable materials, feedstocks, and/or value-added products, this model not only minimises environmental and input costs but also creates new revenue streams. For example, ICEC-MCM investigates how Manufactured Carbonaceous Materials (MCMs) can be cascaded for soil conditioning, demonstrating the potential to optimise land usage for soil generation. However, the complexity of waste treatment processes poses challenges, requiring significant investment in technologies and the efficient design and management of take-back systems to ensure the success of this model.

The energy recovery and CO_2 capture model involves recovering embodied energy, often through facilities like the waste heat recovery boiler at incineration plants and landfills. Firms can also capture CO_2 and use it as inputs for other production processes such as in metal mills and/or for manufacturing other chemical products (value sharing). This model offers advantages in energy savings and maximised energy utilisation, as unused energy from one process can be repurposed for others. In addition, it contributes to Net Zero targets by reducing energy-related emissions. However, like other models, it also suffers from the high upfront investment in technologies and facilities that enable capturing and storing energy and CO_2.

The **linear economy movement** model represents a gradual transition of firms' operations from traditional linear economic activities to CE practices. It involves adopting incremental measures, where firms set internal benchmarks to monitor their progress. For example, tracking annual waste reductions can help assess whether CE initiatives are effectively reducing waste and benefiting the business (Moraga, et al., 2019). This approach is appealing for companies with limited resources, as it does not require extensive investments. However, it often leads to slow transitions, lower competitiveness, and less focus on fully integrating circular principles.

NICER Programme and research outcomes indicating the dynamics of CE practices.

- Diverse CBMs implemented in practice, relying on the PSS concept: Tesla's leasing program, BMW and Daimler's shared vehicles, and CastLab's on-demand metal casting model (Business models in the metal industry by CircularMetal).
- The "rewear" concept embraced by Pangaia, considered an example of a circular textile company.
- Caterpillar remanufactures diesel engines and GreenPower Solutions refurbishes electric vehicle batteries for energy storage as studied by CircularMetal.
- Celtic Renewables' business model, as analysed by CircularChem, centers on recovering value from residual by-products generated during the whisky manufacturing process.
- MCMs can be cascaded for soil conditioning, demonstrating the potential to optimise land usage for soil generation as studied by ICEC-MCM.

Each key CBM mentioned above can inspire the development of related specific models tailored to different industries and needs. For example, the circular products model can lead to business practices like renting (e.g. WeWork desks or private offices), leasing (e.g. Tesla's vehicle leasing), service-based solutions (e.g. Philips' pay-per-lux services). These models can be tailored to fit various industries by considering both internal and external factors.

Note that technologies are pivotal in driving innovations in several circular operational areas. Key technologies advancements like data analytics, blockchain, artificial intelligence, and Internet of Things platforms are critical in supporting the transparency and efficiency of circular processes (resource traceability). These technologies enable material traceability, real-time resource management, predictive maintenance, and seamless collaboration across value chains, all essential for achieving a sustainable CE.

In summary, the most effective circular solutions vary across industries due to unique operational characteristics and waste utilisation practices.
For instance, strategies such as remanufacturing, refurbishment, and repurpose—where old, worn, or non-functional items and components are rebuilt or restored to serve their original or alternative purposes— are popular in sectors like automotive, textile, metal, and machinery. In contrast, implementing circular models for the chemical industry presents additional hurdles, as chemicals are often consumables that are difficult to recover once utilised. In such cases, achieving circularity requires prioritising the sustainability of raw materials and designing closed-loop production systems to minimise waste, such as reducing the amount of plastics sent to landfills. Additionally, the energy recovery model can be adopted to capture unused energy, CO2, or repurposing bioenergy to support low-emission production processes.

3. CBM implementation: Barriers and challenges

Transitioning to a CE involves numerous internal and external barriers that hinder widespread adoption and implementation.

The **lack of cohesive and comprehensive policies** supporting CE adoption has resulted in a fragmented regulatory landscape. This variation, especially across both international and domestic regions, creates uncertainty and conflicting regulations, which in turn discourages corporate investment in CE initiatives. The regulatory inconsistency across nations, for instance, have created significant political hurdles in advancing industrial decarbonisation aspirations in the metal industry (CircularMetal). Existing regulations also lack enforceable requirements for product design that facilitate CE principles, leaving businesses with insufficient guidance to adopt circular practices at scale. On the other hand, stringent compliance requirements can impede the adoption of innovative circular technologies and business models. Furthermore, differences between regulations, such as chemical safety standards and end-of-life waste criteria, create legal uncertainties, often leading to a preference for primary raw materials over recycled ones (Grafström and Aasma, 2021). Cross-border trade further complicates matters, as businesses must navigate different regulatory frameworks in various countries. In Responsible Innovation workshops conducted by Met4Tech, the centre found that regulations are crucial to manage behaviours across supply chains.

It is widely recognised that significant **technological barriers** exist, particularly in the development of efficient technologies for utilising alternative feedstocks. For instance, bio-manufacturing of biopolymers is considered a sustainable approach to polymer production in the textile industry (TCC). A key challenge lies in capturing and producing sustainable renewable materials to replace traditional, non-circular ones. Achieving this requires robust cross-industry collaborations and dedicated R&D efforts to create alternatives that are both economically and environmentally viable. Moreover, another major barrier is in scaling up advanced recycling technologies capable of processing a broader range of materials. However, widespread adoption of these technologies faces fierce competition from existing waste management systems, such as incineration plants that often operate under long-term contracts. These contracts are a disincentive for recycling, as they rely on a continuous stream of waste. Furthermore, many advanced technologies are energy intensive, and for them to truly support a CE, the energy used in these processes comes from green sources. In addition, there is a potential mismatch risk between the deployment of new technologies and the evolution of business strategies. Business strategies often evolve in response to market uncertainties and the competitive landscape, making it challenging to align technological advances with shifting business models (Munaro and Tavares, 2023).

Material challenges, such as managing secondary materials, ensuring their quality, preventing contamination and enhancing traceability, often deter businesses from integrating recycled inputs into their production processes. For example, the significant variation of materials within industries like textiles requires clear sorting and grading. These uncertainties can affect product performance, regulatory compliance, and overall reliability, making companies hesitant to integrate circularity into their production processes. Similarly, consumers share concerns over the reliability and safety of products made from recycled materials, fearing compromised performance and warranties (Grafström and Aasma, 2021). Nevertheless, as revealed by Met4Tech, the diversity of supply is an essential part of responsible sourcing, contributing to overcoming material challenges (Responsible Innovation in Met4Tech).

The successful implementation of CE initiatives faces substantial **financial barriers**. High **capital investments** are required for infrastructure, technologies, and business model shifts. CE projects typically have longer payback periods, which discourages investors who seek quicker returns. The complexity of the ecosystem—ranging from sourcing sustainable feedstocks to managing logistics for collection, sorting and recycling—exacerbates the perception of CE projects as high-risk investments. At current technological levels, greener alternatives (e.g. recycled materials, bio or captured carbon-based products) are often more expensive than conventional (e.g. fossil fuel-based) feedstocks. The **price disadvantages** intensify these challenges, particularly in sectors where the growth of CE practices is constrained by feedstocks availability. Conventional fossil-based processes often do not account for the real environmental cost, and the oil and gas sector benefits from tax breaks that make fossil-based products artificially cheap, creating a financial disadvantage for sustainable alternatives. This creates a substantial barrier for customers to adopt sustainable products, meaning significant costs incurred by firms to educate customers and the long-term R&D investment to achieve price parity over time.

Moreover, the lack of the accessible funding specifically tailored to CE initiatives remains a critical barrier. Small businesses, in particular, face operational difficulties without a comprehensive and efficient system in place, making the implementation of circular models both difficult and costly (Munaro and Tavares, 2023). Last, but not least, the long-standing reliance on traditional supply chains and business models creates a degree of inertia (sunk interest) that makes the transition less palatable. There is a concern that going for the circular route makes businesses less competitive in a global market. This mindset can lead to a situation where companies wait for others to "jump first" before they commit themselves, thereby creating a stalemate situation where no one commits to the transition. In an interview with the CE Hub, Head of Circularity at Zalando, Laura Coppen, indicated that the biggest challenge for adopting CE models is how to change mindsets towards a CE, especially since the linear economy has been considered to be successful for so long.

Table 2. Examples from NICER Programme demonstrating barriers and challenges of the transition to a CE

No	Example/case study from NICER Programme	Contribution
1	A study by CircularMetal mentioning the regulatory inconsistency between nations creating barriers for circularity in the metal industry.	How regulatory barriers influence the transition to a CE.
2	Responsible Innovation workshops conducted by Met4Tech.	These workshops investigated regulatory roles in managing behaviours in supply chains and the diversity of supply, which is crucial for responsible sourcing.
3	A study on bio-manufacturing of biopolymers by TCC.	This study investigates technologies barriers in the textile industry.
4	An interview with Head of Circularity at Zalando conducted by the CE Hub.	This interview reveals the importance of changing mindsets towards circularity.

4. Motivating investment in the CE: All actors' efforts

Despite a significant increase in circular investment flows over the past decade aimed at transforming the current linear economy, these investments remain relatively small. For instance, corporate spending on the CE is estimated at just $850 billion annually, compared to the $35 trillion in linear economy, with circular initiatives making up only 3% of total global investment each year (Barrie et al., 2023).

4.1. Significant financing barriers rooted in both internal and external factors.

The barriers previously discussed not only hinder the implementation of CBMs but also intensify financial constraints towards CE businesses/initiatives. Among the most critical obstacles are **regulatory challenges**, which impact both investors and CBM adopters. CE practices are inherently long-term, requiring significant capital investment. Without a stable regulatory framework and supportive legislation, companies are reluctant to adopt CBMs, and investors are unwilling to extend their investment horizons.

> **Demystifying series: Policy Making and Circular Economy by the CE Hub**
>
> In a series of papers by the CE Hub aimed at demystifying the CE, a set of policies supporting the transition to a CE was discussed, including information and volunteer approaches (e.g. public training and education, labelling programmes and certifications), technology support policies (e.g. investments in infrastructure for a CE, R&D, digital adoption), market-based instruments (e.g. taxation, charges on inputs or outputs, penalties, incentives, etc.), and command and control (e.g. certifications, reporting, performance standards, etc.). Furthermore, the importance of consistent policies was highlighted to facilitate the transition to a CE.

Technological barriers, material limitations, and **operational challenges** are not confined to individual firms, they permeate entire industries, creating risks and uncertainties for investors. Investors tend to prioritise investment projects where risks can be mitigated independently. However, the complexity of CE activities makes it difficult for any single company to de-risk in isolation. Instead, collaborative efforts across the supply chain are essential for effectively addressing these risks (systems thinking).

Other key issues include the **knowledge gap** on CE principles and technologies, and a **lack of standardised measurement frameworks**, which limit the growth of investments in CE (Grafström and Aasma, 2021). Moreover, the economic benefits of a CE have not been fully recognised or realised, resulting in a scarcity of suitable financial products and resources dedicated to CE practices. From the investor's perspective, confidence increases when sufficient information is available to support informed decision-making. However, the absence of comprehensive databases - such as those providing material inventories and waste information - along with limited tools for modelling CE activities, creates significant obstacles. This lack of resources makes it challenging for investors to fully integrate non-economic performance factors (e.g. recycling rates, resource productivity) into the screening and assessment of CE opportunities (Munaro and Tavares, 2023).

> **Measuring Circular Economy implementation and performance through KPIs – CE-Hub working paper November 2023**
>
> In this working paper, authors discussed different approaches and recent developments in measuring a CE. The report confirms the need for a more systematic taxonomic approach to the development of CE KPIs, aligning with key CE principles at multiple measurement points, different scales, and across the whole ecosystem.

4.2. CE funding requirements and availability varies at each distinct stage.

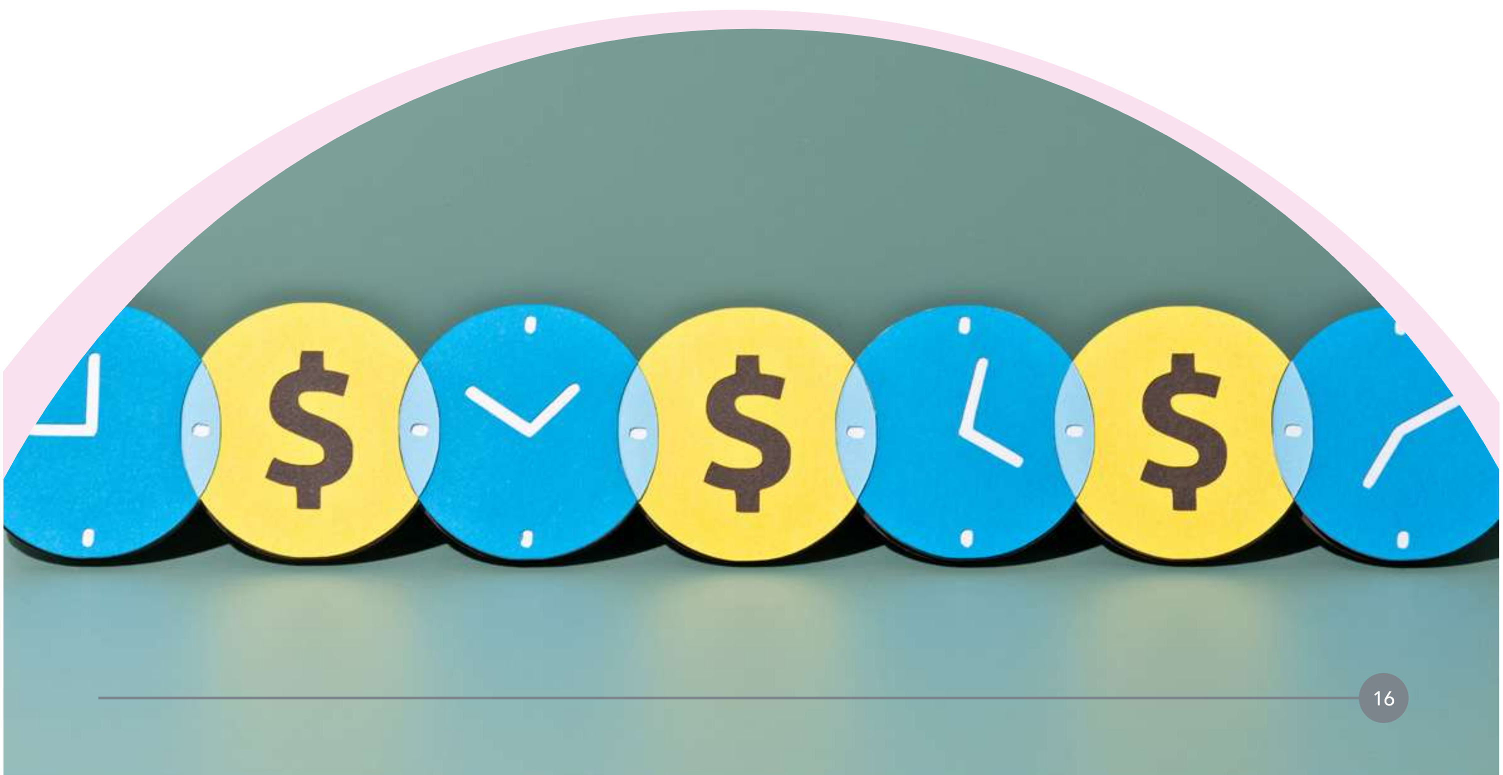
Investment in circular-related technologies is particularly prominent (Ellen MacArthur Foundation and McKinsey, 2015; European Commission, 2019), although most of these technologies remain in the early stages of their development.

Developing circular-related technologies presents a unique challenge. Unlike duplicating existing modules or facilities, these projects cannot be easily standardized. Each development stage involves varying production scales, requiring companies to demonstrate both technological and economic viability. Consequently, the level of required investment differs significantly. For instance, constructing a small-scale chemical plant costs tens of millions of dollars, and a large plant costs billions of dollars (American Chemistry Council, 2023). These substantial financial requirements often make it challenging for companies to secure funding, particularly for commercial-scale deployment and further development.

Once circular-related technologies are successfully commercialised and validated at one plant, companies typically aim to build additional facilities, expanding production capacities, and achieving economies of scale. This progression is critical for reducing production costs and making sustainable products more affordable.

However, raising capital for plant construction and scaling production remains a major hurdle for companies engaged in CE projects.

On the other hand, funding availability for circular businesses varies across different phases of development (Figure 1). In the early stages, businesses primarily rely on public funding sources, such as grants, subsidies, or guarantees, which support initial technological innovation and proof-of-concept activities. They may also access equity financing through angel investors, venture capital, or private equity, to fund the construction of pilot, demonstration, or commercial scale plants. As businesses progress to later stages, such as commercial-scale deployment, and scaling-up and standardising phases, funding availability improves. During these phases, they gain access to debt financing and initial public offerings (IPOs), as their business models become more established and less risky. Debt financing offers a cost-effective funding option, but it typically imposes stringent requirements for de-risking, demanding a high level of project viability. While Figure 1 suggests that circular businesses have access to various funding options in theory, in reality many struggle to secure adequate resources in practice, particularly during high-risk phases. This financial bottleneck can slow down technology development and, in extreme case, lead to business failure. The specific risks associated with circular-related technologies often exceed the risk tolerance of financial investors, who generally seek shorter-term economic returns on investment.



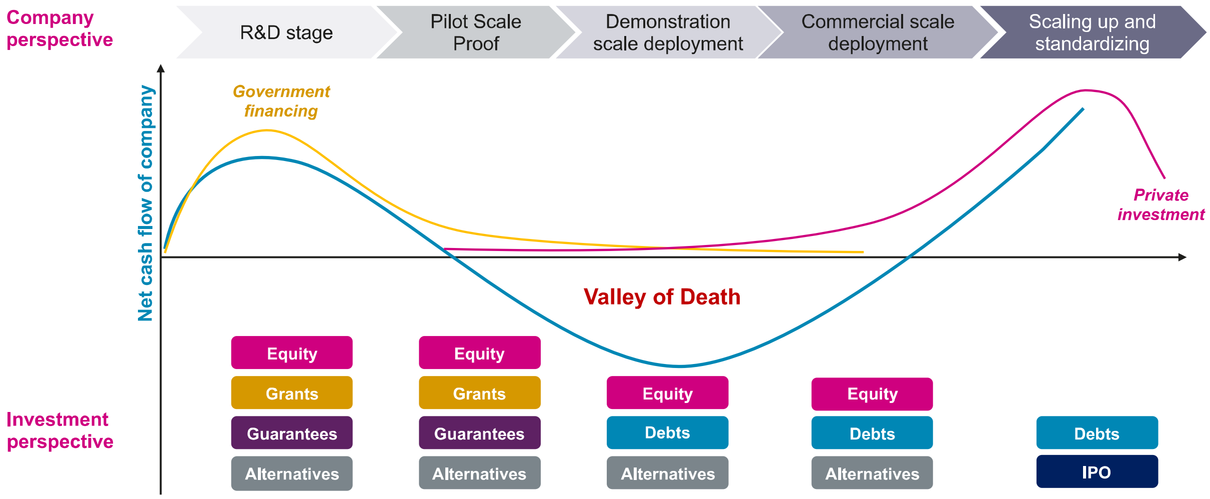


Figure 1. Development stages and corresponding financing sources for circular-related technologies

On a more optimistic note, new investors and innovative financial instruments are increasingly supporting circular-related technologies. Strategic investors tend to be more willing than financial investors to accept the risks associated with CE projects. These investors—whether individuals or companies—focus on long-term strategic benefits, such as fostering innovation or operational synergy, rather than immediate financial returns. For example, businesses engaged in chemical recycling and circular carbon often secure funding from strategic investors, often large companies within their value chain transitioning toward circularity. These investments enable the integration of circular technologies while advancing the investors' broader sustainability goals. Beyond providing capital, strategic investors may offer non-financial advantages that help mitigate the risks in circular projects. These may include signing long-term supply or demand contracts, licensing technologies for use in other regions, providing market access through established networks, or boosting visibility to attract additional investors.

The Strategic Partnership between LanzaTech and Brookfield

LanzaTech exemplifies innovation in industrial symbiosis, showcasing how partnerships and diversified investment strategies can bridge funding gaps. Throughout its development, LanzaTech has met significant challenges in raising funding for building and operating facilities from the demonstration to commercial stages and successfully crossed the funding gap by depending on diversified investors.

Once its core technology had been validated by the successful operation of the first commercial plant, Lanzatech attracted more investors internationally, including Brookfield Renewable, the flagship listed renewable power company. They reached a funding commitment of $500 million in initial investment in 2022.

The use of an infrastructure fund played a pivotal role in this success. The fund provided upfront investment and subsequent funding tied to milestone achievements, such as progressing from a pilot plant to a demonstration plant, reducing the need for repeated investor searches and due diligence. By streamlining access to financing, the infrastructure fund accelerates the construction of new plants and validation of new technologies or products.

Financial investors, typically enter at a later stage of circular products, once these initiatives have proven their financial viability and have the potential to scale rapidly. However, this does not suggest that financial investors are any less important than strategic investors. Rather, from the research phase to scaling and standardisation, circular-related technologies require different types of investors to provide both financial and non-financial support. Financial investors, such as banks and institutional investors, are particularly valuable in the scaling-up phase, where they can offer substantial funding at relatively low interest rates, which are vital for circular businesses seeking to expand operations and achieve greater impact. To expedite financing for CE initiatives, attention must be directed towards institutional investors. In 2022, UK institutional investors managed ~£8.8 trillion in assets (The Investment Association, 2023), making them pivotal in accelerating investment into CE practices. Additionally, given that CE practices are often considered as a subset under the wider sustainability umbrella, alternative financing approaches, such as sustainability-aligned financial instruments (green bonds, sustainability-linked loans, green loans), blended finance, project finance and crowdfunding, can significantly enhance the flow of capital into circular ventures (Kumar et al., 2023).

Circularity Capital

Circularity Capital serves as an insightful example showing how private capital can drive the growth of the CE. This private equity firm specialises in investing in growth stage circular businesses, demonstrating the potential for commercialisation and scaling-up. To date, Circularity Capital has raised over 260 million euros and invested in more than 16 SMEs (shown in the table) that integrate circular principles into their businesses. The firm attracts funding from a diverse range of sources, including global institutions, pension funds, insurance companies, investment banks, high net-worth individuals, and family-office investors. In addition to prioritizing circular businesses, Circularity Capital offers relatively long-term funding. Investors, exemplified by Circularity Capital, are increasingly recognising the opportunities which a CE represents. However, when securing private investment, it is essential not only to meet the requisite return on investment but also to demonstrate and provide evidence of a measurable environmental impact.

Themes	Principles	Invested firms
Circular use model	Alternative ownership models including rental and subscription, that drive product life extension, utilisation and reuse.	Bike Club; REBIKE; Lendis; Grover; ACS
Circular products & materials	Businesses making or remaking circular products or materials.	Cocogreen; Shark Solutions; PackBenefit; CERAFILTEC; Matsmart Motatos
Enabling solutions	Businesses offering proprietary technology solutions or services that help other companies enhance circularity or improve resource efficiency.	TrusTrace; CEMAsys;P2i; ZigZag; Winnow; Green Home Group

Source: From Circularity Capital website

The Zero Waste Scotland Circular Economy Investment Fund

The Zero Waste Scotland Circular Economy Investment Fund is a notable example of how blended finance can effectively bridge the financing gap for CE practices. By pooling resources from both public and private sectors, the fund offers essential support to businesses – particularly SMEs -as they transition to CE models. Through a combination of loans and grants, it has enabled numerous companies to overcome financial barriers and invest in eco-technologies and infrastructure. This demonstrates how collaboration between government and private finance can successfully drive circular innovation.

5. A Comprehensive System Approach to Accelerate Changes

While several successful initiatives demonstrate the practical application of CE principles, offering valuable lessons and highlighting the enablers of a successful transition to a CBM, a key question remains: **where should businesses and other actors focus their efforts to address challenges and promote more circular solutions?**

5.1. Success stories

The success of CE initiatives is rooted in effective collaborations among diverse stakeholders within the overall CE ecosystems (systems thinking). These collaborations enable more efficient use of resources and allow each stakeholder to leverage their unique capacities and competencies.

Furthermore, well-planned circular activities ensure timely and effective decision making, while the acceleration of technological innovation and knowledge exchange drives progress in CE practices. Customising local or firm-specific strategies, along with proactive engagement with different CE principles, is also crucial for success. These initiatives highlight the dynamic nature of CE adoption and implementation in practice, offering businesses the flexibility to develop their own tailored CE models that align with their specific circumstances and needs.

1. **Circular Buildings Coalition:** A partnership among the World Green Building Council, Ellen MacArthur Foundation, and Arup is driving circularity in the built environment by documenting materials for reuse and recycling, promoting designs that allow for easy disassembly, encouraging the efficient use of materials, and advocating for policies supporting circular construction practices (Circular Buildings Coalition, 2024).

2. **Community-Based Circular Supply Chains and Service-Based Models:** Localised, service-based strategies are driving circularity and economic resilience, especially in industries like textiles (Ellen MacArthur Foundation, 2024). For instance, Yodomo, a London-based research and innovation lab, focuses on textile reuse and upcycling. It collaborates with the textile industry to reduce waste while creating affordable and sustainable materials (Yodomo, 2024). Along with this, community-led initiatives highlight the importance of localised supply chains towards waste reduction and better performing materials. These efforts highlight the value of localised solutions and stakeholder involvement in advancing the CE.

3. **Industrial Symbiosis:** This initiative promotes collaboration between firms within the same industry or across different sectors to recover waste or exchange surplus resources. This concept encourages the repurposing of waste materials as valuable inputs for other production processes, helping participants to minimise waste, reduce operational costs, and achieve both economic and environmental advantages. A notable example of industrial symbiosis is the collaboration between Unilever, LanzaTech/Shougang Group and India Glycol (Unilever, 2021). In this partnership, LanzaTech's innovative technology captures carbon emissions from steel mills and converts them into ethanol. This ethanol is then used to produce surfactants, which are key ingredients in Unilever's detergents. By replacing conventional surfactants made from fossil fuels with those produced from recycled carbon, the collaboration not only contributes to reduce carbon emissions but also supports the development of a circular supply chain.

4. **Circular Metal Manufacturing:** Porthos is an example of circular metal manufacturing in the context of Carbon Capture, Utilization, and Storage (CCUS). Located in Rotterdam, Porthos has achieved a notable reduction in emissions through its implementation of CCUS technologies at metal mills (Porthos, 2024). Meanwhile, innovations from Oak Ridge National Laboratory emerged surrounding metal recycling and reuse with automated and self-disassembly systems (Oak Ridge National Laboratory, 2021). In addition, Fab Labs is a digital fabrication laboratory, which aims to empower local communities by democratising access to tools required for technical innovation. These labs are fostering local innovation and customization, especially in the manufacturing industry (Fab Foundation, 2024).

5.2. The dynamic roles of key actors and their interplay to accelerate CE implementation.

Despite the progress in implementing CE practices, the UK economy is still far from achieving full circularity. There is no "silver bullet" solution to delivering a CE. Instead, it requires a comprehensive, whole system approach, involving all actors—businesses, policymakers, consumers, financiers, and innovators—to implement the transformative changes needed. The following recommendations are based on the analysis of the current challenges, requirements for accelerating the CE transition, with a particular focus on the corporate level. These recommendations cover perspectives of four key actors: firms, supply chains, policymakers, and investors.

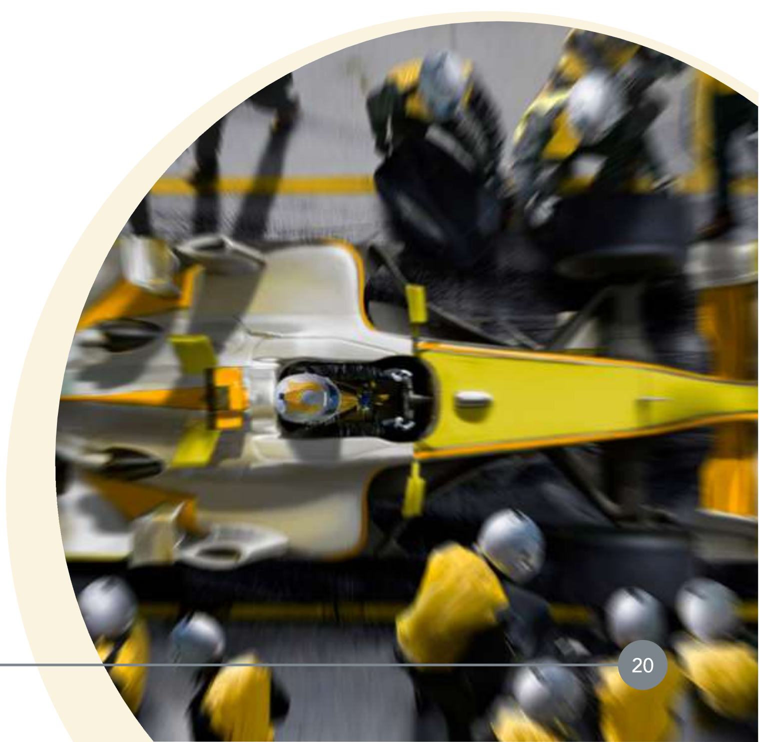


Table 3. Key recommendations for accelerating a CE

Actors	Business model	Financing
Firm	• Embed CE principles into **business strategies and culture**, enabling iterative improvements and adaptation to both internal changes and external market and regulatory shifts. • **Effectively manage stakeholders** by segmenting investors, suppliers, commercial buyers, and consumers based on behavioural and socioeconomic characteristics, such as willingness to pay, willingness to invest, and other key factors. • Ensure the **mutual benefits and risks** are shared among partners. • **Leverage technologies** in circular practices for optimising resource use, waste reductions, and extending product lifecycles. • Build robust **internal and external system-wide networks**, including industry symbiosis, to co-create values, cascade resources, and minimise wastes. • **Enhance data validation** by providing technical data for new technologies, leveraging operational data for risk assessment, and prioritising materiality considerations.	• **Engage diverse funding sources**, such as CE-linked funds, green bonds, sustainable-linked loans, while aligning with suitable capital structure. • **Create financial buffer** through maximising the use of internal resources (e.g. extending payable periods, shortening receivable periods). • Design financing mechanisms that cater to **different stages of technological innovation**. • Develop suitable cost structure, integrate CE activities and enable the evaluation of **investment effectiveness** in CE activities.
Supply Chain	• Encourage larger companies to enhance investor confidence by **making commitments** to purchase from circular/green sources/suppliers. • Promote **green procurement** and sustainable supply chain practices. • **Leverage economies of scale and standardised manufacturing facilities** to lower costs and reduce price differential between conventional and circular products. • **Educate consumers** about recycled product consumption through providing recycling labels, customer engagement events, involving customers in the CE process, and collaborating with others to promote circular consumption.	• **Leverage cutting-edge digital technologies** to enhance data transparency across the value chain, improving investor confidence. • **Large companies** can **increase strategic investment** to achieve innovation synergies, drive competitiveness, and promote circularities.
Policymaker	• Create regulations and supportive frameworks that **promote market growth and stability** and that foster **sustainable consumptions**. • Establish stable and comprehensive policies that **attract long-term CE investments**.	• Introduce **government-led initiatives**, such as disclosure mechanisms, to boost transparency and foster confidence in CE investment. • Utilise **blended finance** approaches that combine public and private investments to mitigate risks and attract a diverse pool of investors.
Investor	• **Provide professional expertise** to support firms in scaling and commercialising CE technologies more rapidly. • Encourage **leading investors**, such as institutional investors, to take the lead in financing CE projects, creating momentum for broader investor participation and risk-sharing.	• **Bridge the knowledge gap**, broaden selection criteria, and improve CE project assessment. • Develop and leverage **novel financial instruments**, such as green and circular linked financing, to fund CE initiatives effectively.

Conclusions

Circular business opportunities vary across different industries. Selecting the right model hinges on a firm's business strategy, organisational capabilities, and the external environmental drivers of its operations. Even though individual businesses may adopt different CBMs, these strategies must align with the core principles of the CE to ensure that CE concepts are embedded not only into their business models but also into wider network strategies and operations.

However, implementing a CBM is a complex endeavour. Success depends on consolidating a shared vision among stakeholders, where values, benefits, and risks are equitably distributed. Achieving this requires joint efforts across the business network, timely access to information, adequate funding to support circular practices, and the availability of enabling technologies that can facilitate circular operations.

To overcome the challenges of CE implementation, firms need to adopt a system approach, considering internal and external drivers. A firm-centric view is insufficient for accelerating the CE; instead, deep supply-chain integrations and even inter-supply chain collaborations are critical to driving the success of CE businesses. This integrated approach will be essential for unlocking the full potential of circular practices across industries.

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