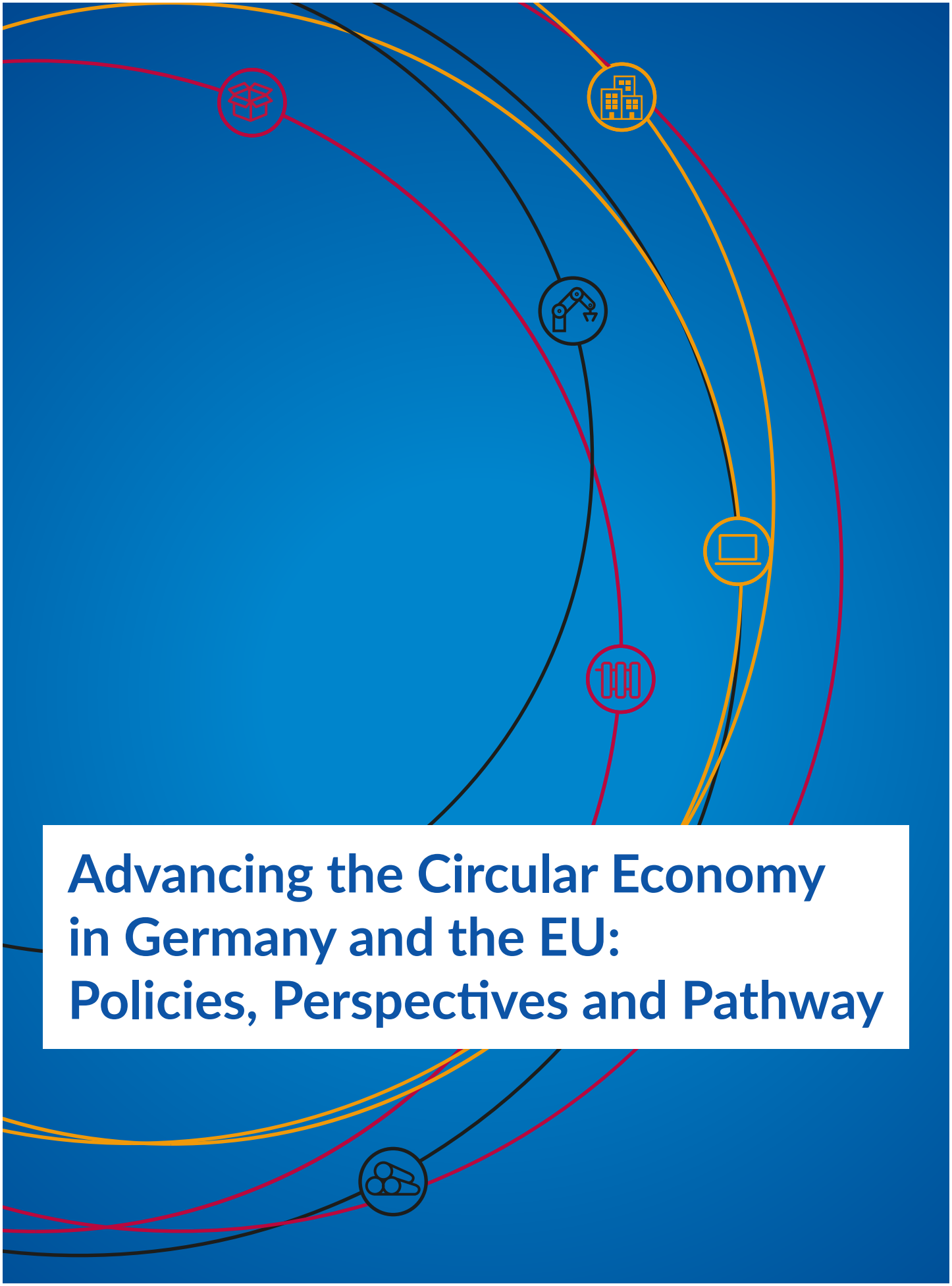

Advancing the Circular Economy in Germany and the EU: Policies, Perspectives and Pathway

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Contents

Introduction: Navigating the diversity of perspectives on the circular economy

Economic and lifestyle patterns in Germany – and in much of the world – exceed the planet's ecological limits. In response, governments, businesses and civil society actors worldwide are working to reverse this trend, advocating for a shift toward resource-efficient economic models based on circular economy principles. The circular economy challenges the traditional linear approach of resource consumption – characterized by "take, make, dispose" – by promoting the continuous circulation of materials. Its primary goal is to curb environmental impact by minimizing what is conventionally classified in the linear economy as waste. As the circular economy gains traction – reflected in policy initiatives, expanding research and corporate strategies – expectations surrounding its implementation have become more ambitious and complex. Against the backdrop of multiple, overlapping crises – including climate change, biodiversity loss and geopolitical instability – access to critical raw materials has become increasingly strategic. Many now see circular economy strategies as a potential game changer, offering a way to reconcile economic growth with environmental sustainability and reduce resource dependency. But can the circular economy truly live up to these expectations?

A diverse range of stakeholders has embraced the concept, from environmental groups, industry leaders and policymakers – particularly at the EU level – to civil society organizations and local governments. However, the term "circular economy" encompasses a variety of interpretations, each emphasizing different priorities. Table 1 provides an overview of key dimensions within circular economy debates, illustrating how different conceptual approaches build upon one another. In German-language discourse, multiple terms are used to describe the circular economy. For consistency, this study adopts Kreislaufwirtschaft as an equivalent to circular economy (for further discussion of terminology and its varying connotations, see Garcia Schmidt et al. 2023).

Competing visions and policy approaches

Efforts to promote resource circularity at the European level date back to the European Community's first Environmental Action Programme in 1973 (Bækgaard et al. 2024). In Germany, early legislative foundations were laid with the 1994 Circular Economy and Waste Act, which initially framed circularity in terms of recycling waste and valuable materials. For decades, this approach – focused on technical, end-of-pipe environmental solutions – addressed the symptoms of resource depletion rather than the underlying economic structures, behavioral patterns or systemic inefficiencies driving waste generation (Stumpf & Baumgartner 2022). Since 2015, the EU has taken a more structured approach with its first Circular Economy Action Plan, followed by an expanded strategy in 2020. Most member states have since adopted national circular economy policies, though their scope, implementation strategies and levels of ambition vary significantly (EEA 2024; UNIDO 2024; Wilts & Bröcker 2022; Pinyol Alberich 2022). Both academic research and real-world applications of circular economy models reflect a wide spectrum of interpretations. Kirchherr et al. (2023) exam-

TABLE 1: **Diversity of perspectives on the circular economy**

Dimensions of the circular economy

Focus of circular economy impacts	Lifecycle phase	Eco-innovation approaches	Scope of application	Key actors	Policy objectives / governance context
Climate action, environmental protection, emissions and waste reduction, land degradation, energy efficiency	Production processes and industrial practices	Process and material innovation (technological innovation)	Businesses / Industrial sectors	Waste management and economic development agencies (national, regional, local)	Advancing waste management and recycling systems
Reducing reliance on critical raw materials (Open Strategic Autonomy)	Product design	Organizational and strategic innovation (business models, marketing)	Global supply chains	Economic and industry stakeholders	Minimizing waste, pollutants and emissions
Enhancing industrial competitiveness and economic resilience	Consumption and use phase	Consumer behavior and market transformation (behavioral innovation)	Cross-sector collaboration	Innovation agencies (national, regional, local)	Improving resource efficiency and securing raw material supply
Economic efficiency and productivity gains	Post-use and recovery phase	Governance and stakeholder coordination (social innovation)	Regional networks (e. g., "Circular Cities")	Research and development institutions	Strengthening ecosystem resilience and service sustainability
Social sustainability: health protection, employment, equity	Cross-cutting: Business models	Process innovation and systemic transformation	Consumers / consumption patterns	NGOs, civil society and user groups	Advancing societal well-being and sustainable lifestyles

Source: Diversity of perspectives on the circular economy
(Source: Future Impacts / Bertelsmann Stiftung, own analysis of 20 publications, see appendix)

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ined 221 definitions of the circular economy, identifying both common principles and points of divergence. Some approaches prioritize efficiency – maximizing resource productivity and minimizing waste – while others align with sufficiency-oriented and post-growth economic models that advocate reducing overall consumption. Still others emphasize nature-based economic design, integrating circular principles into broader sustainability frameworks (Acatech 2019; Stumpf & Baumgartner 2022; SRU 2024). A growing body of scholarship also explores the circular economy's potential for addressing social inequalities by restructuring economic systems to be more just and inclusive (Bækgaard et al. 2024). Despite these differing perspectives, one common thread runs through circular economy discussions: it is not an end in itself but a strategic framework for sustainable economic transformation. The intended outcomes of this transformation, however, vary widely. Some prioritize resource conservation and climate mitigation, while others focus on strengthening corporate competitiveness, reducing reliance on foreign suppliers, or fostering local job creation and economic resilience (Acatech 2019).

In European debates on the circular economy – among policymakers, industry associations, think tanks, environmental organizations and foundations – three primary perspectives can be identified (Calisto Friant et al. 2021; Baekgaard et al. 2024, see Figure 1):

FIGURE 1: **Overview of different perspectives on the circular economy**

Circular economy framework	Technocentric approach	Reformist approach	Transformative approach
Key areas for change	Primarily focused on corporate production processes and end-of-life recycling	Companies take responsibility for their environmental footprint across the entire product lifecycle, developing new business models Consumers: Shifting consumption patterns Regional impact: Innovation, job creation and circular material flows	Aimed at reducing absolute resource consumption Economic and social restructuring of the system
Intended-outcomes	Resource security Climate protection Eco-efficiency	A driver of green growth Job creation Innovation	Aligning economic activity and consumption with planetary boundaries A fair and socially just economic model

Source: Future Impacts / Bertelsmann Stiftung, based on Calisto Friant et al. 2021

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- The **technocentric perspective** focuses on technological solutions and innovations to improve production processes and waste management. Here, the circular economy is primarily seen as a tool for optimizing manufacturing, treating waste as a resource input. The emphasis is on cost reduction through eco-**efficiency.** Rooted in a market-liberal approach, this discourse assigns primary responsibility for implementing circular economy principles to manufacturers and suppliers.
- Expanding on the corporate-driven, technocratic model, the **reformist perspective** sees the circular economy as a driver of green economic growth and job creation. Environmental protection, resource conservation and emissions reduction are integrated as overarching objectives. This approach broadens the scope of action beyond corporate process optimization to include societal and consumer engagement. Local governments and civil society organizations are recognized as key actors alongside businesses, which are expected to take greater responsibility for minimizing their environmental footprint. Consumers and their purchasing behaviors also play a central role. Innovative business models are seen as critical to advancing circular economy goals (Pinyol Alberich 2022).
- The **transfomative perspective** sets the most ambitious expectations for the circular economy, arguing that economic and consumption patterns must operate within planetary boundaries and that absolute reductions in resource use are necessary. Beyond economic restructuring, advocates of this approach call for a broader social reorganization toward a more equitable and just economic system.

The role of digitalization

The wide-ranging perspectives on the circular economy underscore the complexity of integrating materials and products from diverse sources – manufacturers, service providers and consumers – into a cohesive system. A clear understanding of how consumption and production impact the environment, society and the economy is essential for developing systemic circular economy solutions. Strengthening knowledge and awareness helps identify key levers for shaping sustainable value propositions, corporate strategies, policy priorities and consumer choices. Digitalization is widely regarded as a key driver of circular economy transformation. It enables the systematic collection, sharing, and integration of relevant data into decision-making processes (Berg et al. 2024; Hedberg & Šipka 2020). Within this context, digitalization is framed as part of the broader discourse on the twin transition – the simultaneous shift toward a digital and sustainable society, in which technological advancements are leveraged to advance sustainability goals (Acatech 2024; BBS 2022; BBS 2024; JRC 2022).

Objectives and approach of this paper

Given the diverse interpretations of the circular economy, this paper aims to contribute to the ongoing discourse on sustainability and the circular economy. It provides an overview of key topics currently shaping discussions in Europe and Germany, focusing on aspects that can accelerate and advance the transition toward circularity. A particular emphasis is placed on enabling factors and key levers that drive this transformation – in other words, identifying actionable needs and opportunities. This paper complements the prevailing regulatory and technocratic perspectives on the circular economy with a potential-oriented, European (and partially global) lens, offering new insights that have so far been underexplored in the German debate.

The paper examines the following key themes:

- The circular economy must move beyondrecycling efforts
- Unlocking the potential of the circular bioeconomy
- Circular business models require radical redesign
- Embedding ethics in the circular economy: from local to global

These themes were identified through a systematic review of relevant publications on the circular economy in Germany and Europe. Details on the methodology and a full list of analyzed sources are provided in the appendix. The core analysis is based on 20 evidence-based publications that either explore various perspectives on the circular economy or focus on specific conceptual approaches. These sources span academic research, think tanks, industry associations and stakeholder networks to ensure a broad representation of viewpoints. Each chapter of the paper delves into one of the key themes, discussing major debates, future challenges and critical levers for change identified in the reviewed literature and beyond. The cross-cutting theme of digitalization is examined across all four areas. The conclusion synthesizes key takeaways, particularly those most relevant for Germany's circular economy transition.

Priority issues: An overview

Circularity involves more than recycling

Circular economy policies often focus narrowly on technical aspects and material flows – largely because fossil-based and inert raw materials are finite, and supply chains depend on a small number of providers. As a result, many current initiatives emphasize recycling but rarely go further.

However, the digital and green transitions – including renewable energy, energy storage and electric mobility – rely on a range of critical raw materials that are economically vital to the EU. With supply concentrated among a handful of producers and few viable alternatives, disruptions pose a significant risk. Geopolitical tensions are compounding these vulnerabilities, threatening stable access to essential raw materials and components. While recycling efforts have made only limited headway, broader strategies to reduce resource consumption – such as repair and shared-use models – must be pursued. Expanding these approaches is a critical part of de-risking supply chains and advancing both political goals, such as the EU's push for open strategic autonomy, and corporate priorities, including long-term supply security.

Unlocking the potential of the circular bioeconomy

Discussions on circularity tend to focus on technical material cycles, while biological cycles remain largely overlooked or confined to niche applications. Yet biological and biochemical materials hold significant, untapped potential to replace fossil-based resources with renewable, bio-based alternatives. Harnessing this potential could secure more sustainable raw material sources and transform residual materials into high-value inputs for new products.

Biological cycles are inherently circular: natural materials break down and re-enter the ecosystem as nutrients, sustaining the cycle of life. By substituting fossil-based and environmentally harmful materials with bio-based alternatives that have a lower ecological footprint, it may be possible to reduce reliance on finite resources through sustainable biomass production. However, scaling a circular bioeconomy requires careful trade-offs, particularly in balancing food security, biodiversity and environmental protection.

Circular design requires bold thinking

The design phase – whether for products or services – is the most powerful lever for advancing circular business models. Moving beyond incremental efficiency gains requires both creativity and a willingness to take risks, embracing radical new ways to meet consumer needs sustainably.

The key decisions that shape circularity happen at the design stage: What materials are used? What is their environmental impact? How recyclable or toxic are they? Can components be easily disassembled, repaired or repurposed? What business models support extended product lifespans and reuse? A truly circular economy requires rethinking consumption itself – challenging whether a product or service is necessary and whether it creates lasting value in a sustainable way.

Embedding ethics in the circular economy: from local to global

For the circular economy to drive real transformation and contribute to a more socially just economic system, it must be built on a strong ethical foundation. Fairness, equity, inclusivity and health protections cannot be afterthoughts – they must be embedded in policies and business practices. But ethics in circularity is not just a moral imperative; it is key to securing broad-based support, from local communities to the global economy. This perspective extends beyond domestic and European markets to global supply chains, shaping the working and living conditions of people worldwide.

A truly circular economy is values-driven, recognizing its responsibility not only for environmental sustainability but also for human well-being. Ethical principles therefore play an important role in actors' credibility. While European discussions on the "just transition" largely focus on mitigating labor market disruptions within the EU, the global social dimension of circularity remains underexplored. Key issues such as labor rights, workplace safety in raw material extraction, recycling and repair industries, as well as protections for gig workers in sharing- and service-based models, must be addressed both within Europe and globally. If circular economy policies fail to account for growing regional and global inequalities, they risk losing public and political support.

Cross-cutting issue: Digitalization as a key enabler for the circular economy

Key message: The shift from a linear to a circular economy fundamentally changes how information flows and knowledge is managed. Digitalization is a critical enabler of this transition, with far-reaching applications that go beyond its current use.

To fully implement circular economy principles, businesses and policymakers need better data and insights across entire supply chains – from production and usage to repurposing and end-of-life options. For example, materials from used products often have different properties than newly manufactured ones. At the same time, circular business models depend on seamless coordination among diverse value chain partners. Digital tools can be a game changer, helping to overcome these challenges and scale circular solutions to the mass market.

The circular economy must move beyondrecycling efforts

Key message: Circular economy policies often focus narrowly on technical aspects and material flows – largely because fossil-based and inert raw materials are finite, and supply chains depend on a small number of providers. As a result, many current initiatives emphasize recycling but rarely go further.

"The concept of the circular economy shifts attention to the entire product lifecycle, integrating it into the broader value creation network." (Böckel et al. 2022)

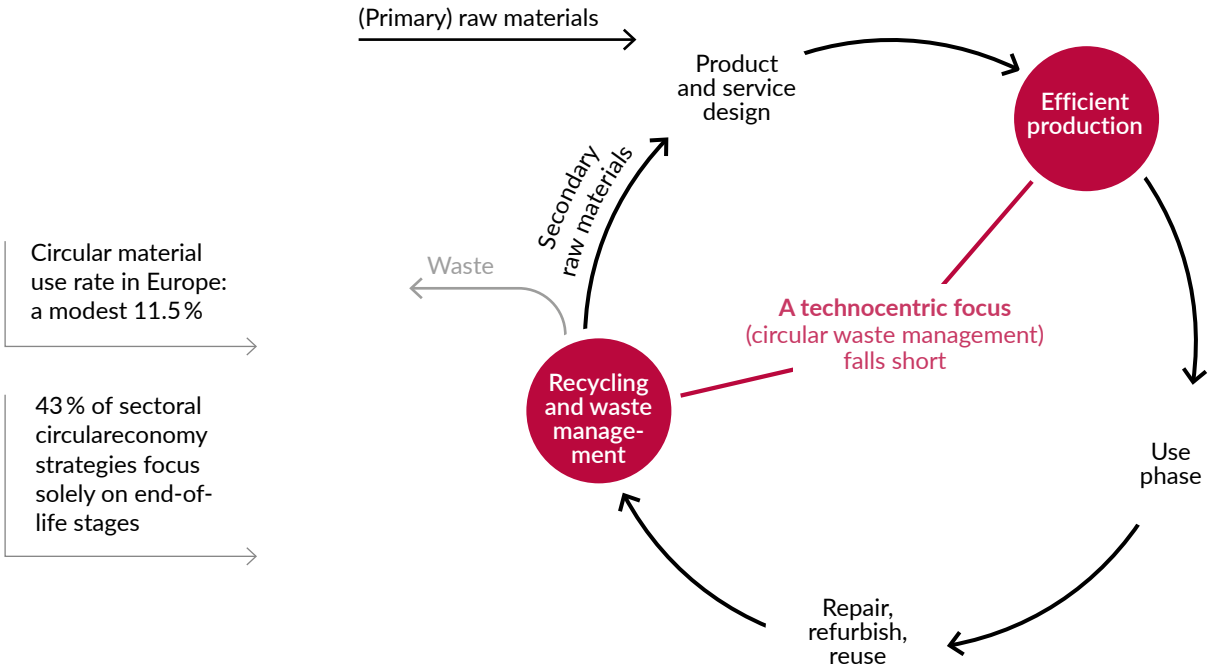
At its core, the circular economy aims to maximize the value of products, components and materials by keeping them in use for as long as possible (Acatech 2023; Böckel et al. 2022). Yet in practice, the global economy remains far from achieving this goal. EU policies continue to focus primarily on the technical and economic dimensions of circularity, while more ambitious strategies – essential for a competitive and resilient circular economy – have been slow to materialize (Calisto Friant et al. 2021). Currently, nearly half of all EU sector-specific circular economy strategies remain concentrated on end-of-life solutions: 24 % focus on recycling, while 19 % prioritize waste disposal (de Pascale et. al. 2023; see Figure 2).

According to estimates, just 7.2 % of materials globally are reused, while the EU's circularity rate stands at only 11.5 % (see Figure 3) – measured by the Circular Material Use Rate, which tracks the share of recycled materials in total resource consumption (EEA 2024; Circle Economy 2024; Hedberg & Šipka 2020). In 2022 alone, 35 % of the five billion metric tons of materials processed in the EU became waste (EEA 2024). The construction sector is a prime example: it generates 450 to 500 million metric tons of waste annually, yet recycling targets are rarely met (Hedberg & Šipka 2020).

This shortfall is not just an environmental concern – it is an economic risk. Increasing circularity could cut CO_2 emissions from Europe's heavy industry by nearly 50 % by 2050 (Hedberg & Šipka 2020). On the economic front, circular strategies could generate €600 billion in annual savings across the EU while improving material efficiency by 3 % through optimized resource flows (Institut National de l'Economie Circulaire 2020, WEF 2023). Estimates suggest these changes could boost European GDP by 7 % to 10 % (Institut National de l'Economie Circulaire 2020, Hedberg & Šipka 2020).

Critics argue that Germany in particular has yet to decouple resource consumption from economic growth, suggesting that its circular economy is better described as "circularity-oriented waste management" (Acatech 2021). While the country achieves high – though often loosely defined – recycling rates in terms of volume, it makes little use of broader systemic strategies, such as

FIGURE 2: **Limitations of the predominant technocentric focus on recycling and production efficiency**



Source: Future Impacts / Bertelsmann Stiftung; basic closed-loop cycle based on EEA 2024, Circle Economy 2024, Bahn-Walkowiak et al. 2019; Daten von de Pascale et. al. 2023, EEA 2024

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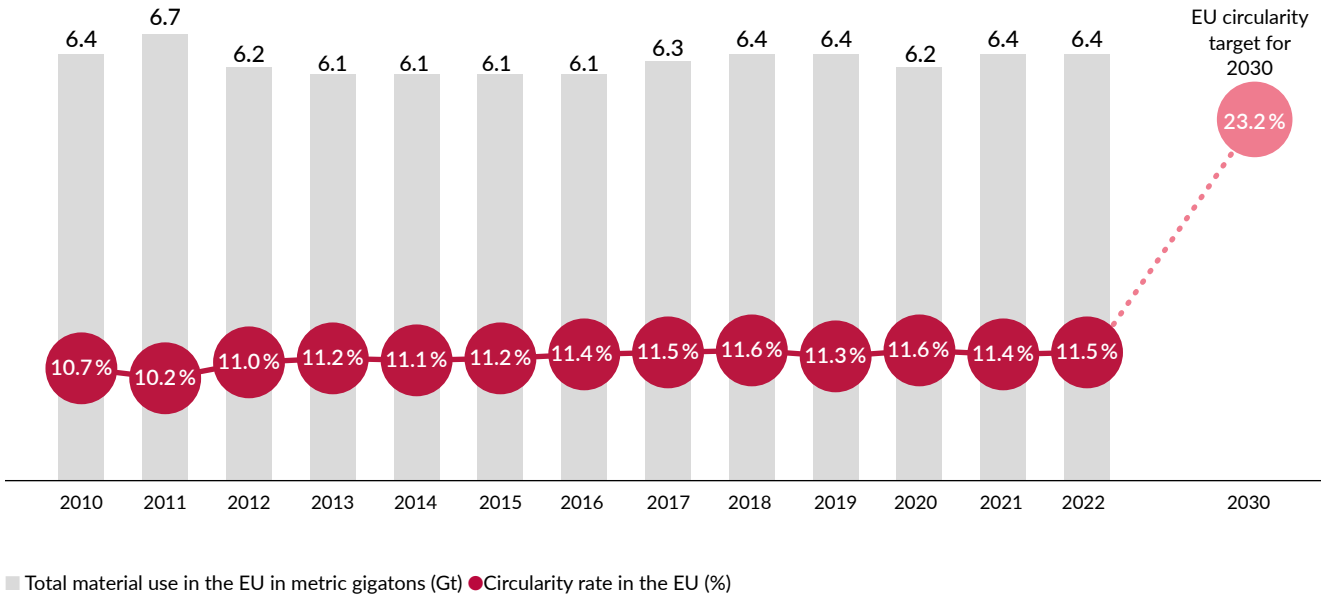
FIGURE 3: **Trends in circularity rate and domestic material consumption in the EU27, 2010 – 2022**



Total material use in the EU in metric gigatons (Gt) ●Circularity rate in the EU (%)

Source: Own presentation by Future Impacts / Bertelsmann Stiftung based on data on the circular material use rate (env_ac_curm) from EEA 2024 and on resource consumption (Domestic Material Consumption env_ac_mfa) from Eurostat 2023

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extending product lifecycles and creating more effective closed-loop systems (Acatech 2021).

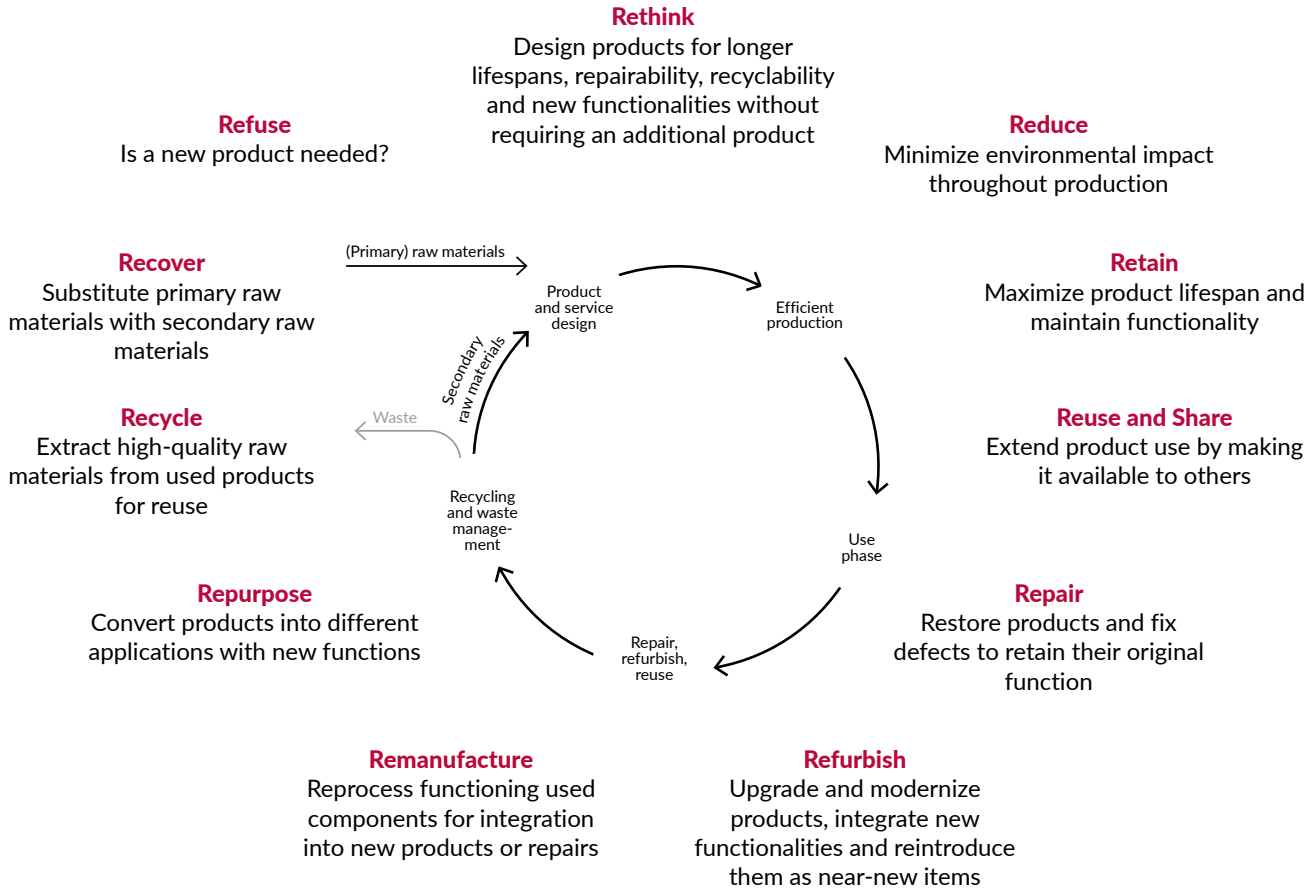
The circular economy is not just an environmental imperative – it is increasingly a question of economic and geopolitical resilience, particularly given Europe's reliance on global supply chains. In recent years, geopolitical tensions have repeatedly led to efforts to restrict access to strategically important industries, including semiconductors, defense technology and dual-use goods – products with both civilian and military applications. Trade policies and state interventions limiting access to raw materials and key inputs have become common tools in this strategic competition, making resource security an increasingly critical economic and political issue (Maihold 2022). While global resource consumption continues to rise, the EU has managed to stabilize – or in some cases slightly reduce – its overall material use despite economic growth (EEA 2024, Circle Economy 2024; see Figure 3). However, progress has been uneven across different resources. Between 2000 and 2022, the EU's consumption of metal ores and non-metallic minerals – such as sand, gravel and limestone – increased by approximately 10 %. This makes accelerating circular economy strategies particularly urgent for the 34 materials classified as critical under the EU's Critical Raw Materials Act, including copper, nickel, lithium, and manganese (EEA 2024). These resources are essential for clean energy technologies, digitalization and mobility, and viable substitutes for many of these materials are scarce (Irrek 2022). Thus, extending product lifespans and improving collection and recycling systems are crucial to reducing demand for virgin resources (EEA 2024, Bækgaard et al. 2024, Beyeler & Böckel 2022, Bahn-Walkowiak et al. 2019). According to a U.S. study, secondary raw materials could meet up to 90 % of the demand for critical materials in low-carbon technologies – including battery storage, electric vehicles, solar panels and wind turbines – by 2050 (EEA 2024). However, recycling progress remains concentrated in base metals such as aluminum, copper and iron, as well as in glass, paper and cardboard (Prognos 2024). The variety of specialized composite materials and the effort involved in collecting, sorting, dismantling and extracting raw materials have posed a significant challenge to significant success with recycling in these areas (Prognos 2024).

Future challenges and enablers in transitioning to a circular economy

Faced with the urgent need to roll out the full suite of circular economy strategies before, during and after product use – the so-called R-strategies: Refuse, Rethink, Reduce, Retain, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover (Potting et al. 2017; Stumpf & Baumgartner 2022; EEA 2024, see Figure 4) – a host of technological, market, institutional and sociocultural hurdles must be overcome (de Pascale et. al. 2023). On the tech front, breakthrough innovations are essential to cut reliance on critical raw materials. In many cases, phasing out these materials isn't feasible – for instance, rare earth elements remain indispensable for the permanent magnet generators in wind turbines – and doing so can trigger trade-offs, such as diminished energy efficiency in electric motors (Irrek 2022). The answer lies in championing designs that make products easier to recycle, whether by avoiding complex composite materials or by ensuring items can be disassembled and fed back into the production cycle. Moreover, strategies like urban mining are emerging as promising avenues for sourcing raw materials. Realizing these opportunities will require ramping up innovation and fostering closer collaboration along supply chains, all within a supportive regulatory framework (Agora Industrie 2023, Bahn-Walkowiak et al. 2019, DERA 2023).

Integrating global value chains means managing intricate flows of products and materials. At the same time, applying sustainability criteria demands a careful balancing of competing priorities – think recyclability versus energy consumption in production (Hedberg & Šipka 2020). Digitalizing processes is a linchpin in many circular economy strategies. Collecting and sharing data for evidence-based decision-making is key to measuring circularity and unlocking resource savings (Berg et al. 2024, Pinyol Alberich 2022, Hedberg & Šipka 2020). In this context, a digital product or material passport can fill critical information gaps – detailing what materials are in a product and how it can be disassembled or recycled – while cutting transaction costs. This added transparency provides a clearer view of the supply and availability of secondary raw materi-

FIGURE 4: **R strategies of the circular economy**



Source: Own presentation by Future Impacts / Bertelsmann Stiftung;
basic closed-loop cycle based on EEA 2024, Circle Economy 2024, Bahn-Walkowiak et al. 2019;
R strategy approaches according to Potting et al. 2017, Stumpf & Baumgartner 2022; EEA 2024

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als across entire value chains and helps set fair prices for longer-lasting products (Acatech 2023, Berg et al. 2024, Calisto Friant et al. 2021).

Yet there is still a clear need for innovation in digitalizing circular processes, particularly in areas like interoperability, blockchain applications, and artificial intelligence. Investments in digital infrastructure and updates to regulatory frameworks – especially regarding data protection – are also crucial. Charting a clear policy course here is challenging given how deeply integrated Germany's and Europe's economies are in global value chains, making international cooperation essential (Hedberg & Šipka 2020).

Concrete policy targets for the circular economy, paired with a comprehensive action plan to achieve strategic goals, offer a promising route to unlocking its full potential. In fact, 48 % (15 of 31) of the operational strategies or roadmaps reviewed by UNIDO from various countries include quantitative macroeconomic targets for the circular economy – though most of these targets, covering waste, recycling and resource productivity, are nonbinding (UNIDO 2024). For example, the German Circular Economy Strategy, adopted in December 2024, sets a nonbinding goal to cut per capita primary raw material consumption from today's 16 metric tons to between six and eight metric tons by 2045, in line with recommendations from the UN Environment Programme's International Resource Panel (BMUV 2024).

Yet the current economic model fails to assign a monetary value to natural capital, so environmental costs – like the externalities of primary raw material extraction – aren't captured by market mechanisms. As a result, dominant linear production and consumption patterns persist (Hedberg & Šipka 2020). Moreover, market tools such as taxes, incentives and subsidies that could internalize these costs and help establish a robust market for secondary raw materials often lag behind (de Pascale et. al. 2023). This is where government regulation, particularly at the European level, becomes critical – whether in market oversight, competition law, standard-setting or fiscal policies that shift the tax burden from labor to products (Bækgaard et al. 2024, Circle Economy 2024, Econsense 2021, Stumpf & Baumgartner 2022). European harmonization is essential to send a strong signal to all market players (Institut National de l'Economie Circulaire 2020).

Unlocking the potential of the circular bioeconomy

Key message: Beyond technical aspects, the biological cycle is often relegated to niche debates – even though it spans both biological and biochemical materials. Yet the opportunity to replace fossil-based inputs with renewable, bio-based alternatives represents an underutilized potential to tap sustainable raw material sources and transform residual materials into inputs for new products.

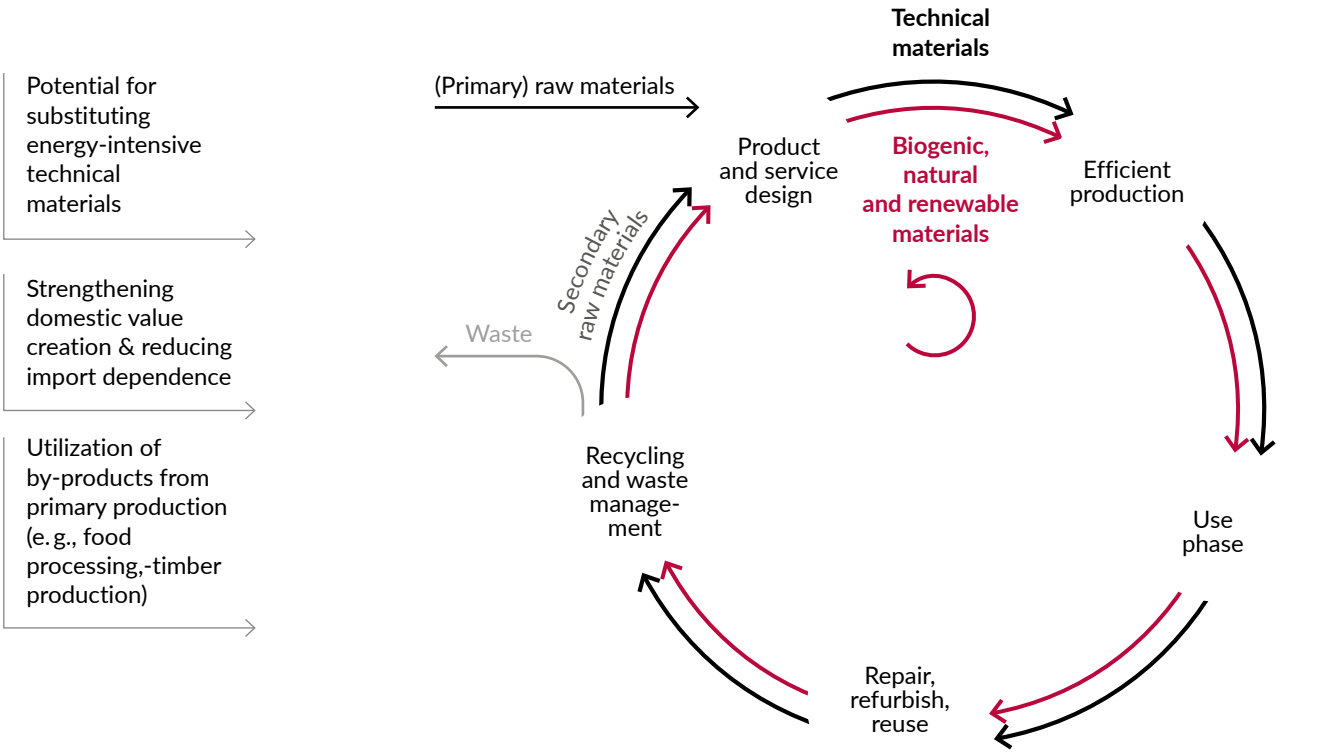
"Put simply, a biocircular economy is an economy powered by nature."
(Marshall et al. 2023, p. 806)

Bioeconomy refers to economic systems that generate, process and deploy biogenic – namely, natural and renewable – resources. These resources come from agriculture, forestry, fisheries, and marine industries (for example, algae), while the circular bioeconomy emphasizes a greater use of biogenic residues, bio-waste and CO_2 (Kircher 2023). This approach unlocks sustainable alternatives to fossil resources – such as bioplastics produced from cellulose derived from sugars instead of petroleum. So far, natural resources have been predominantly used in construction, energy, packaging and textiles (EEA 2024, see Figure 5).

The biological resource cycle is woven into the fabric of foundational circular economy models, like the Ellen MacArthur Foundation's "Butterfly" diagram (2013; see also Acatech 2019) and Braungart and McDonough's Cradle-to-Cradle approach (von Unruh & Mast 2022). Yet, it tends to play a peripheral role in current circular economy debates. In contrast, circularity takes center stage in bioeconomy strategies at multiple levels – featured in vision papers from Europe's forestry sector (e.g., Forest-based Sector Technology Platform 2019; Coalition for Circular Choices 2023), the European Bioeconomy Strategy (EC 2018; JRC 2023), the new EU Forest Strategy for 2030 (European Commission 2021), and the German National Bioeconomy Strategy (Bundesregierung 2020), along with similar documents from more than 60 countries worldwide (Marshall et al. 2023). In Germany, for instance, research institutes from the Fraunhofer-Gesellschaft delivered a roadmap for a circular bioeconomy to policymakers in 2022, underscoring that sustainable, resource-efficient and climate-friendly practices are both achievable and necessary (Fraunhofer-Gesellschaft 2023).

Across the EU (27 countries), roughly 1.2 billion metric tons of biomass are produced each year. About half of that is used for food, feed and animal bedding, 22 % for bioenergy, and 28 % for materials (EEA 2024). Forestry products are chiefly channeled into construction, as well as the furniture, paper and packaging industries (EEA 2024). New product categories – such as cross-laminated timber (CLT) for lightweight construc-

FIGURE 5: **Core aspects of the circular bioeconomy**



Source: Future Impacts / Bertelsmann Stiftung; basic closed-loop cycle based on EEA 2024, Circle Economy 2024, Bahn-Walkowiak et al. 2019

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tion, wood foam for insulation, or wood-based textile fibers like lyocell – are broadening the field of applications (FAO 2022). In agriculture, roughly equal amounts of primary outputs (notably food, feed and timber) and by-products or residues are generated, varying by production type. In agriculture, roughly equal amounts of primary outputs (notably food, feed and timber) and byproducts or residues are generated, varying by production type. Examples include straw, press residues, bark and in forestry, branches, leaves and sawdust (JRC 2018). These residues are already widely repurposed – as green manure, or in the production of biofuels, biogas or fibers – and they also offer new opportunities, such as serving as feedstock for bioplastics. Compared with traditional construction materials like concrete and steel, these bio-based products can be significantly more climate-friendly by sequestering CO_2 during their useful life and enabling or expanding production processes in prefabrication, renovation or building extensions (Marshall et al. 2023; Holden 2022).

Within a circular economy, it's crucial to look beyond mass-produced goods and tap into a broader range of raw materials. In addition to timber and its byproducts, forestry yields a variety of niche and secondary products. These include nonwood items such as forest fruits, mushrooms, pine nuts, chestnuts, acorns, cork, essential oils, medicinal herbs and decorative materials. Together, these products account for an economic value exceeding 70 % of Europe's annual roundwood yield (Lovrić et al. 2020; Wolfslehner et al. 2019). Their distinct qualities make them well suited for premium applications – from health and nutrition to interior design – and they offer untapped opportunities to advance a circular bioeconomy.

Future challenges and enablers in transitioning to a circular economy

A circular bioeconomy isn't about simply boosting agricultural and forestry output – it's about embracing sustainable production in line with cradle-to-cradle principles. The aim is to prevent pollutant inputs, improve soil productivity, conserve water resources, protect biodiversity, cut greenhouse gas emissions and secure long-term carbon storage (Cradle to Cradle NGO 2021). A critical benchmark is that raw material extraction must never compromise food security. Repurposing residues from agriculture and forestry as biogenic raw materials is a key strategy to ease land-use conflicts, lower water consumption and reduce reliance on agrochemicals. Moreover, using carbon dioxide as a feedstock plays a central role in climate change mitigation; for example, cultivating microalgae captures CO_2directly from the air, and that biomass can be converted into algae-based fuels, textile fibers, oils or fatty acids (Fraunhofer-Gesellschaft, 2023).

It's clear that technological innovation – especially in production processes – is vital for a circular bioeconomy. Bio-refineries are needed to break down wood-like raw materials and residues into platform chemicals such as ethanol, glycerin, glucose and acetone, which can stand in for basic petrochemicals (IUFRO, 2024). Bio-based chemicals, fuels and fibers must compete head-to-head with conventional products on both price and quality. Bolstered support for research and development, pilot projects in industrial settings and robust quality standards will be essential to make these new biological products competitive in the market.

Digitalization is also seen as a major lever for scaling a circular bioeconomy. First, digital monitoring can help ensure that sustainability benchmarks in raw material production are met – tracking everything from resource footprints and climate impacts to effects on biodiversity and potential clashes with food production (Fraunhofer-Gesellschaft, 2023). Second, a digital product passport can store and communicate product specifications and recycling options. Third, digital twins – virtual replicas of physical assets and processes – can pinpoint areas with untapped potential for enhanced biomass production or carbon sequestration, drawing on geographic surveys of agricultural, forestry and natural lands (Fraunhofer-Gesellschaft, 2023). Finally, sequencing the genetic code of plants and animals and archiving this data in international databases offers solutions for a range of challenges, from developing innovative pharmaceuticals and diagnostic tools (as seen during the COVID-19 crisis) to preserving biodiversity and boosting the resilience of species essential for global food and forestry security (Bundesanstalt für Landwirtschaft und Ernährung, 2021; Klünker, 2023).

Circular design requires bold thinking

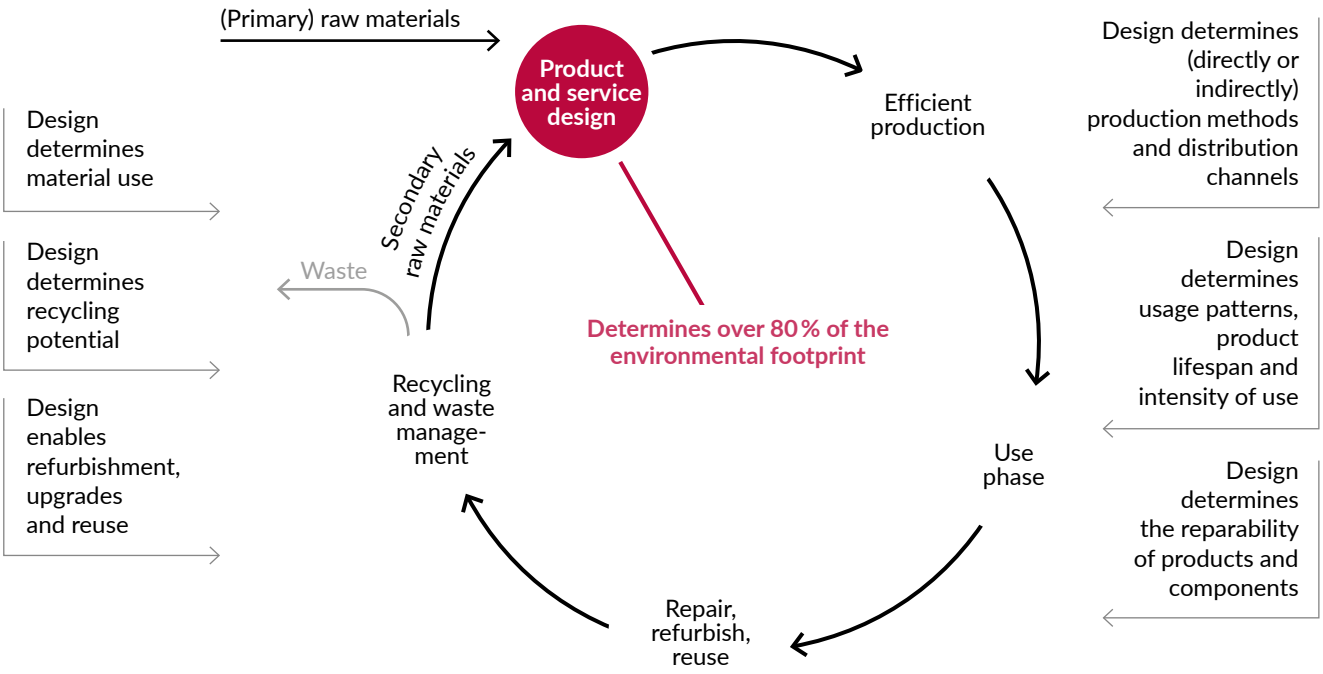
Key message: The design phase – whether for products or services – is the most powerful lever for advancing circular business models. Moving beyond incremental efficiency gains requires both creativity and a willingness to take risks, embracing radical new ways to meet consumer needs sustainably.

"Many circular business model concepts propose placing product-service systems at the heart of business models. This service intensification alters how companies create, offer and capture value." (Acatech 2023).

In the prevailing narrative of industrial or ecological modernization, the circular economy is mostly framed as a technical and economic challenge: Technical inovations in waste management or the use of secondary raw materials are seen primarily as tools to reduce costs. Critics of this narrative argue that focusing solely on efficiency and productivity gains within the circular economy is insufficient to address the broader issue of increasing raw material demand across industries (Bækgaard et al. 2024, Beyeler & Böckel 2022, Bahn-Walkowiak et al. 2019). Thus, the top "R's" in the pyramid of R strategies – "Rethink" and "Refuse" – serve as systemic components that push the conversation beyond material flows themselves (Stumpf & Baumgartner 2022).

A key to implementing such a systemic approach lies in the planning and development of offerings (i.e., products or services), as decisions made at this stage account for up to 80 % of the ecological footprint (Bækgaard et al. 2024, Barkhausen et al. 2022, Berg et al. 2024, Bahn-Walkowiak et al. 2019, Hedberg & Šipka 2020). This is where the groundwork is laid for aligning value chains with closed (technical and biological) loops: Designing for circularity means incorporating elements like potential repairs, technical updates, disassembly, as well as reuse and recycling right from the start (Acatech 2023, EEA 2024, WEF 2023). Further innovations are required to extend product lifespans, at the product, component, and material levels – such as predictive maintenance, repairs, updates, upgrades and overhauls – as well as to intensify the use phase (e.g., sharing products like in car-sharing, renting or using as a service). For many manufacturers focused mainly on product sales with few customer-facing services, this is a radical shift. The most significant change, however, is to fundamentally challenge ("Rethink") or reject ("Refuse") the underlying

FIGURE 6: **Core aspects of the circular bioeconomy**



Source: Future Impacts / Bertelsmann Stiftung; basic closed-loop cycle based on EEA 2024, Circle Economy 2024, Bahn-Walkowiak et al. 2019

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customer need. An example of this is companies focusing on mobility solutions instead of just designing vehicles (Acatech 2023, Stumpf & Baumgartner 2022; see Figure 6).

Approximately 60 % of manufacturing companies in Germany report using "ecodesign," but only 15 % do so to a great extent. Most companies remain focused on traditional resource-saving measures like energy and process optimization (Neligan, 2024). Attempting to integrate isolated elements of circular economy principles into fundamentally linear business models generates insufficient momentum for such systemic shifts; a holistic design of value offerings along circular economy principles could ultimately enhance the business performance of companies significantly (Berg et al. 2024, WEF 2023).

It is increasingly recognized that only a radical transformation of business models can pave the way for a true circular economy (Acatech 2023, Econsense 2021, WEF 2023). With circular practices gaining traction, this insight has become a key competitive differentiator. Proactive measures are essential, as new, nontraditional players – and innovative startups – can disrupt established markets with offerings like product-as-a-service (Acatech 2023). A circular economy demands systemwide innovation that brings together diverse partners to extend product lifecycles, facilitate repairs, promote reuse and boost recycling (Acatech 2023). In short, product innovation must go hand in hand with fresh business models and a rethinking of stakeholder roles throughout the value chain (EEA 2024, Econsense 2021, WEF 2023).

At the same time, a systematic understanding is needed to identify the limitations of business models rooted in traditional growth paradigms. Such models risk triggering rebound effects – where the resources saved in one area are simply consumed elsewhere, negating any net gains. To achieve an absolute reduction in resource use, entirely new economic practices that curb overall consumption are required (Beyeler & Böckel

2022, Calisto Friant et al. 2021, EEA 2024, Hofmann 2022, Pinyol Alberich 2022).

Future challenges and enablers in transitioning to a circular economy

Given the range of obstacles, circular business models often remain in the planning or pilot stage and are confined to niche markets (Acatech 2023, Bahn-Walkowiak et al. 2019, WEF 2023). Closed-loop technical systems that reimagine entire value chains provide strong incentives for companies to fundamentally transform their offerings. Yet these systems are challenging to implement because they rely on achieving scale and fostering collaboration among many stakeholders (Acatech 2023, Hofmann 2022). For example, outdoor retailer Vaude's For example, outdoor retailer Vaude's "Vaude Rent" service offers gear – such as tents, bike bags, backpacks and sleeping bags – for short-term rental during trips or vacations. This model depends on partnerships with digital booking platforms, local sports retailers or rental services, cleaning companies, repair shops, warehousing and logistics providers (Hofmann 2022). Such cross-sector collaboration requires careful orchestration of value creation, optimization and distribution – a key lever for the systemic innovation a circular economy demands (Acatech 2023, WEF 2023).

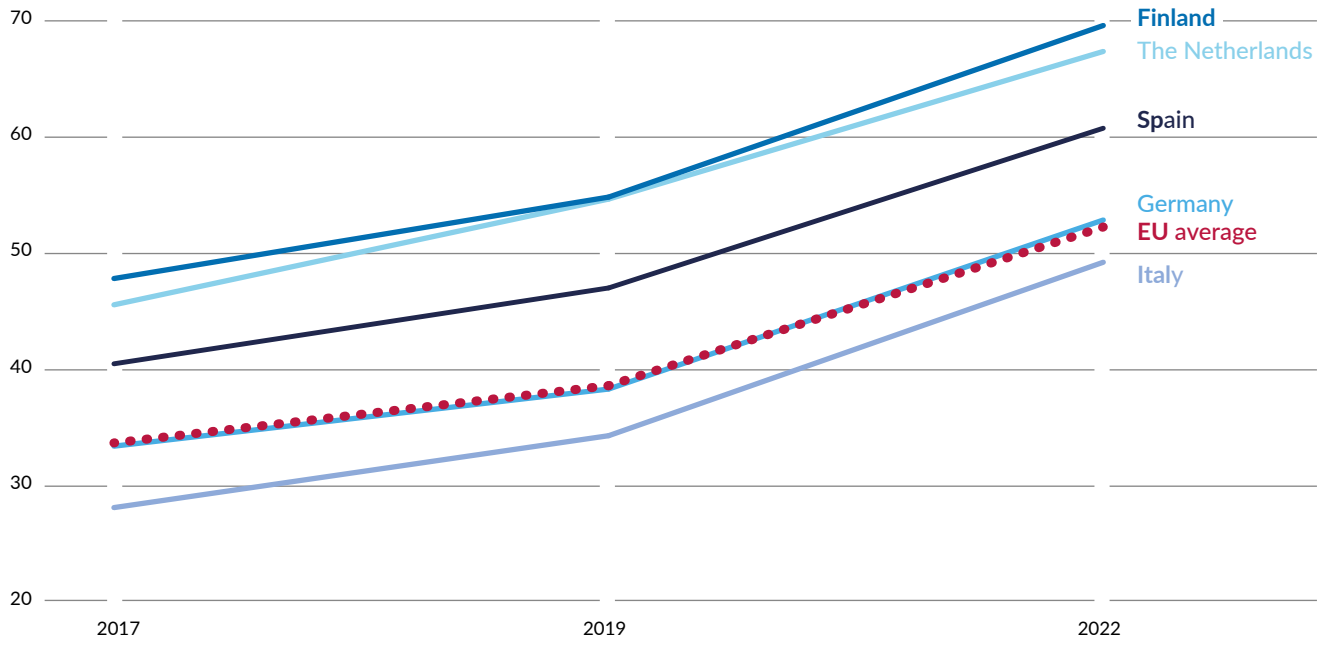
Standardization is also crucial for these collaborations, especially when building integrated, user-centered value cycles. A well-known example is the standardization of the digital product passport (Berg et al. 2024). Additionally, enhanced government support for precompetitive research is vital. Collaborative R&D can provide a "first-mover" advantage that accelerates market entry. These pioneering solutions then set de facto standards that can be codified into binding requirements for products and services (Econsense 2021, WEF 2023). Over time, such standards build trust among market players and enable a wholesale transformation of value chains (Acatech 2023, Barkhausen et al. 2022, Circle Economy 2024, Econsense 2021). It is in the best interest of Germany and the EU to seize the competitive opportunities available today (Acatech 2023, Hedberg & Šipka 2020, Pinyol Alberich 2022). The European Union is a key player here – its stakeholder platforms, such as the European Circular Economy Stakeholder Platform, bring diverse voices together, while EU legislation and economic policies create powerful incentives for change.

Regulation at both the national and EU levels is another critical lever. It helps distribute the risks associated with the innovations needed to adopt circular practices while ensuring that companies receive the right incentives (Acatech 2023, Stumpf & Baumgartner 2022). The EU Ecodesign Regulation, which includes measures such as the right to repair and the digital product passport, sets the first minimum standards, and the EU Extended Producer Responsibility Directive marks another important step (Acatech 2023, Barkhausen et al. 2022, UNIDO 2024, WEF 2023). Furthermore, a mix of regulations, tax breaks and subsidies could further lower transaction costs, adapt product-specific rules, and promote open-source solutions and knowledge sharing (Acatech 2023, WEF 2023). In Germany, developing a unified legislative framework for a circular economy is also crucial (Acatech 2023) – the adoption of the National Circular Economy Strategy (BMUV 2024) is a major milestone in this regard.

From a technology standpoint, digitalization is as important as advanced production methods. Digital technologies are reshaping how value is created, delivered and captured in a circular economy – and in many cases, making it possible in the first place (Acatech 2023, Hedberg & Šipka 2020). The availability of digitally gathered data and the networks they enable are key to product-service systems, which support practices like reuse, predictive maintenance and remanufacturing (Neligan 2024, Hedberg & Šipka 2020, Pinyol Alberich 2022). Notably, Germany ranks only 12th in the European Commission's Digital Economy and Society Index for digital competitiveness, highlighting a significant need to catch up (Acatech 2023, see Figure 7). At the EU level, the circular economy and digital agendas must be more closely aligned (Hedberg & Šipka 2020).

Users of products and services play a critical role in ensuring the success of circular business models. They are not only responsible for closing the loop by engaging with circular offerings throughout a product's lifecycle – through actions such as maintenance, repairs, sharing and recycling – but also for reshaping social expectations that prioritize novelty over sustainability (Acatech 2023, Econsense 2021, Stumpf & Baumgartner 2022; SRU 2024). The EU's

FIGURE 7: **Development of the Digital Economy and Society Index (DESI) 2017, 2019 and 2022 of selected EU countries and the EU-27 average**



Source: Illustration by Future Impacts / Bertelsmann Stiftung; Data: European Commission 2024

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Industry 5.0 initiative provides a promising starting point for a regenerative, circular economy that can prioritize human well-being and progress (de Pascale et al. 2023).

However, additional steps are necessary to address the social and cultural factors shaping the circular economy. This includes rethinking consumption patterns, encouraging open-source collaboration in product development, and supporting the de-commercialization of business models through social and solidarity economy initiatives (Beyeler & Böckel 2022, Calisto Friant et al. 2021, EEA 2024). Central to this approach is the idea of delivering the desired benefits with as little resource input as possible (Beyeler & Böckel 2022, Jaeger-Erben & Szabo-Müller 2022, Kirchherr et al. 2023). Equally important are simple, often non-digital solutions – known as frugal innovations – that dramatically cut costs by focusing on core functions and optimizing performance (Beyeler & Böckel 2022).

Embedding ethics in the circular economy: From local to global

Key message: For the circular economy to drive real transformation and contribute to a more socially just economic system, it must be built on a strong ethical foundation. Fairness, equity, inclusivity and health protections cannot be afterthoughts – they must be embedded in policies and business practices. But ethics in circularity is not just a moral imperative; it is key to securing broad-based support, from local communities to the global economy. This perspective extends beyond domestic and European markets to global supply chains, shaping the working and living conditions of people worldwide.

"It is important to recognise that circular economy systems are not inherently socially beneficial just because they are circular. For example, the shift does not automatically generate more jobs and better working conditions – such co-benefits need to be actively designed into circular economy actions." (EEA 2023, p. 79)

The concept of a circular economy originally emerged from environmental and economic pressures – rising raw material costs, growing waste streams and underwhelming recycling rates – rather than from a social agenda. Although social issues are gaining traction, market forces still largely shape the approach (Global Compact Network Germany and WWF 2024). Even if reform-minded strategies now call for value-based practices and greater corporate social responsibility, and the call for a "Just Transition" takes center stage in European debates, a truly ethical, socially focused circular economy remains out of reach (Bækgaard et al. 2024; Calisto Friant et al. 2021).

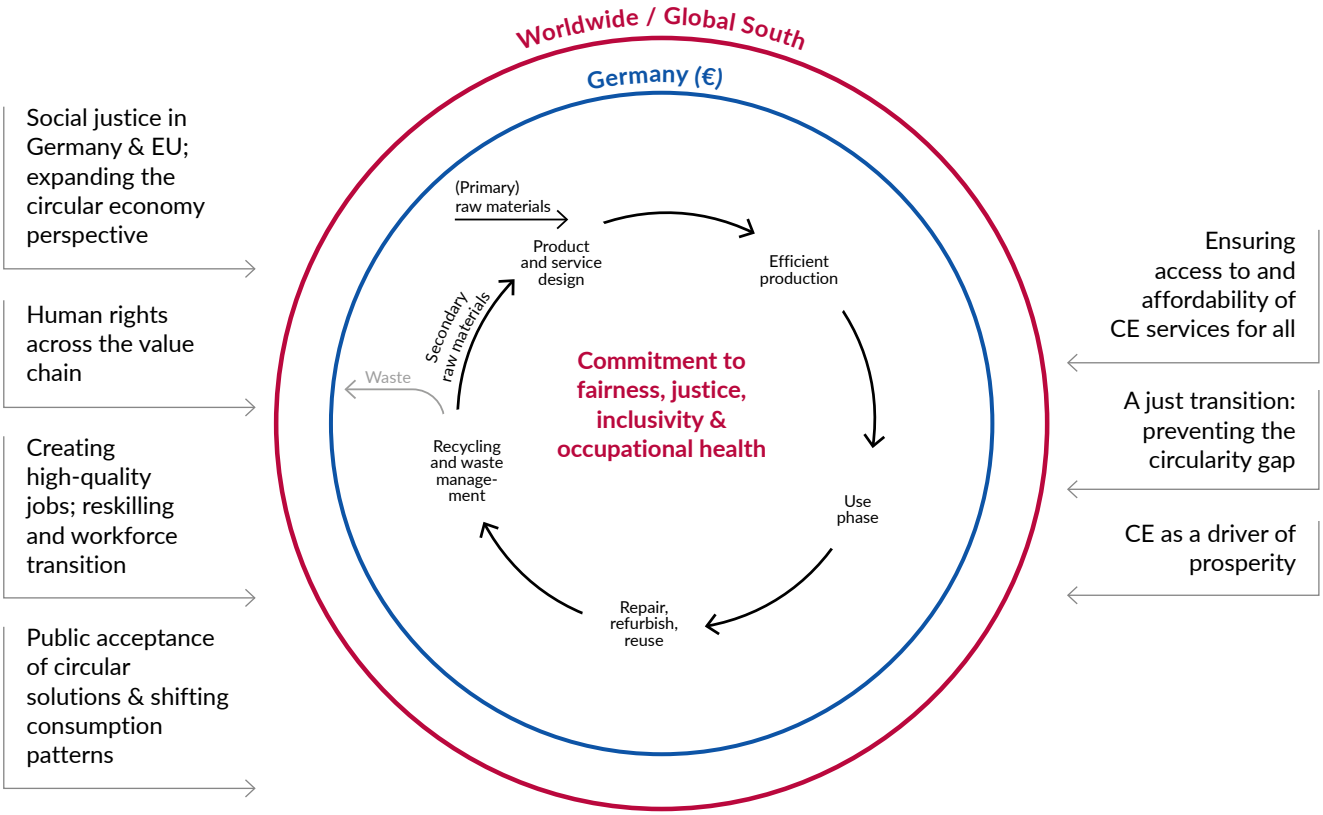
Advocates frequently tout the social benefits of circularity. For example, Econsense (2021, p. 9) highlights cleaner air, fewer human rights abuses in supply chains and the creation of quality jobs. Yet practical initiatives and academic discussions often sideline these social dimensions. Kirchherr et al. (2017, 2023) found that most circular economy definitions overlook social and ethical standards. On a positive note, awareness is growing: while only 19 % of circular economy definitions mentioned social goals – such as health, well-being, a fair transformation or a "circular society" – in 2017, that figure had risen to between 24 and 27 % by 2022 (Kirchherr et al. 2023). This indicates – as does a recent case study of German SMEs (Bertelsmann

Stiftung 2024) – a growing awareness of the importance of social and ethical aspects in the circular economy. Some researchers have begun proposing a "Circular Society" framework that deliberately integrates these dimensions (Calisto Friant 2020; DIN 2023; see Figure 8).

Adopting a global perspective – complementing national and European views – is essential, especially when examining international supply and value chains as addressed by the EU Supply Chain Act. Many recent studies indicate that the transition to a circular economy will have tangible social impacts (e.g., EEA 2024, EU-OSHA 2023). While some current guidelines, such as the "Circular Economy" directive from the Global Compact Network Germany and WWF (2024), focus on business priorities like talent acquisition, brand reputation and customer loyalty, a truly just circular economy must prioritize factors such as working conditions, occupational safety and gender equity – from raw material extraction to recycling, repair, and platform-based product sharing – both in Europe and globally (EU-OSHA 2023; Pansera et al. 2024). Moreover, the employment effects and overall impact on livelihoods from a circular economy are likely to be uneven. For instance, the European Environment Agency estimates that shifting to a circular textile economy could generate up to 85,000 new jobs in the EU while potentially endangering as many as 756,000 jobs in production countries, particularly in emerging and developing regions (EEA 2024).

Moreover, a stark social disparity exists among consumers, as much of the global population cannot afford or access circular products and services due to poverty, gender or disability constraints (UNDP 2024). A prime example is the reliance on peer-sharing platforms, which typically require a stable internet

FIGURE 8: **Perspectives on an ethically designed circular economy (CE = circular economy)**



Source: Future Impacts / Bertelsmann Stiftung; basic closed-loop cycle based on EEA 2024, Circle Economy 2024, Bahn-Walkowiak et al. 2019

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connection – a resource not available to everyone. Clearly, poverty remains a barrier to adopting circular economic practices (UNDP 2024). This reality underscores the urgent need to ensure circular products and services are both affordable and accessible while simultaneously addressing deepening poverty and inequality. The circular economy can serve as a catalyst for broader access to goods and services through sharing models that eliminate upfront purchasing costs – examples include tool libraries, carpooling, clothing or book exchanges and solar kiosks for electricity. For policy leaders seeking to build a truly transformative circular economy, tackling poverty and inequality – both locally and globally – must become a core element of their strategic framework (Bækgaard et al. 2024; Calisto Friant 2020).

Future challenges and enablers in transitioning to a circular economy

An ethical and inclusive transformation is key to ensuring a successful shift to a circular economy. Without it, there's a risk that those sidelined by – or feeling excluded from – a system lacking ethical grounding could reject the change and even push back (EEA 2024). To forestall such resistance, groups like the EEA (2024) and DIN (2023) argue that the decision-making process must be both inclusive and participatory. A forward-looking risk assessment should weigh several factors: job security; the affordability of circular initiatives, products and services; and shifts in consumer habits, long-standing behaviors and cultural norms – such as society's view on ownership.

On the job front, the circular economy is widely seen as a major engine for local employment and economic inclusion (Pinyol Alberich 2022). For instance, social enterprises focused on reuse and refurbishment create roughly 70 jobs per 1,000 metric tons of recovered materials, opening doors for integrating marginalized communities (Ellen MacArthur Foundation 2024). As the circular economy evolves, many occupations and their skill requirements are undergoing significant change. Investing in targeted education and retraining programs ("reskilling") – especially in regions and sectors most at risk – is a promising way to nurture an ethical circular economy (EEA 2024).

If circular measures drive up the cost of basic needs, there's often a call for social policy steps to support low-income households (UNDP 2024; Garcia Schmidt et al. 2023). Moreover, changing entrenched consumer and mobility habits presents a considerable challenge. In this context, offering compelling alternatives – along with clear information, heightened awareness of circular benefits and opportunities for firsthand experience – is essential (UNDP 2024).

A global perspective on raw material–sourcing countries helps identify early warning signs of how the transition to a circular economy might unsettle societies and economies in these regions (Circle Economy 2024). UNIDO (2024) argues that an equitable global transition could prevent a "circularity divide" that would otherwise exacerbate existing global inequalities. A key challenge lies in the fact that transitioning from global primary material supply chains to a circular economy shifts power dynamics within the value chain – for instance, by reducing overreliance on a few sources. It's important to note that industrialized and less industrialized countries differ in terms of technical expertise, innovation capacity, access to financing, bargaining power and digital infrastructure. As a result, countries vary in their ability to drive or manage this transition (EEA 2024). Nevertheless, the move to a circular economy can bolster development prospects in low- and middle-income countries by freeing up resources for building local industries and circular systems. The 2024 Circular Gap Report (Circle Economy 2024) highlights several key strategies for international cooperation: enhancing multilateral collaboration and policy coordination, expanding international programmatic initiatives, identifying mutually beneficial circular economy trade mechanisms, and increasing financing and capacity-building efforts. Lastly, adapting circular economy solutions to regional needs can generate significant local value. Consider, for example, Togo's WoeLab, which creates 3D printers from electronic waste – including discarded printers, scanners and computer parts – a simple yet effective frugal innovation that sparks growth in local economies (Ezeudu et al. 2022).

Cross-cutting issue: Digitalization as a key enabler for the circular economy

Key message: The shift from a linear to a circular economy fundamentally changes how information flows and knowledge is managed. Digitalization is a critical enabler of this transition, with far-reaching applications that go beyond its current use.

"(...) achieving a sustainable CE is one of the most complex challenges of today. Digitalisation is not a silver bullet that can immediately solve all of the challenges (...). However, (...) digitalisation can be an enabler and accelerator for positive change and help address many of these obstacles – as long as it is managed well."
(Hedberg & Šipka 2020, p. 17)

In many twin transition-oriented discussions at both the EU and national levels, digital solutions are seen as a cornerstone for sustainable transformation (e.g., JRC 2022). Digital technologies deliver a wide array of functions that drive progress toward environmentally sustainable and climate-friendly practices in business and everyday life. This is especially true for circular economy strategies. As the preceding sections have illustrated, digitalization acts as a cross-cutting lever across all areas of focus. In a circular economy, comprehensive data and insights are required across the entire supply chain – from production and usage to end-of-life recovery. To fully implement circular economy principles, businesses and policymakers need better data and insights across entire supply chains – from production and usage to repurposing and end-of-life options. Moreover, the material characteristics of used products often differ significantly from their original form. Meanwhile, business models in a circular economy demand the seamless integration of innovative and diverse value networks (Hedberg & Šipka 2020; Berg et al. 2024). In this context, digitalization is the critical tool needed to overcome these challenges and scale circular solutions for the mass market.

Below, we consolidate the digital applications and enabling effects specific to advancing the circular economy, organizing the elements introduced above into four thematic areas (see Table 2).

TABLE 2: **Leverage effects of digital technologies for the circular economy**

Functions of digitalization for the circular economy	Applications and leverage effects
Build an information base that provides data on products, components and materials to support circular resource management, achieve resource efficiency, and craft compelling value propositions	
Provide material and product data (product passports)	Manage complex flows of products and materials across supply chains
	Communicate repair, reuse, upgrade and recycling options (e. g., disassembly instructions, material specifications)
Provide information on the availability and quality of (secondary) raw materials	Offer insights on the availability and quality of secondary raw materials (e. g., through automated, sensor-based wear and fault detection covering products, components and materials)
	Report on the availability of biogenic raw materials and identify opportunities for new biogenic resources
Capture circularity, ensure transparency	Monitor circular economy activities (e. g., processing of secondary raw materials, repair services and "product-as-a-service" offerings)
	Automate data collection for reporting obligations (e. g., statistics, public administration, sustainability reports) using standardized methodologies
Learning from data to address knowledge gaps	Identify potential savings in resource consumption and manufacturing processes (e. g., better machine utilization, reduced startup losses through AI-driven controls)
	Provide decision support for shaping circular economy offerings through AI-enhanced data analysis (e. g., balancing competing priorities, accommodating diverse product use scenarios)
Bringing together and coordinating stakeholders in circular economy networks and innovative business models	
Enable effective stakeholder coordination	Matchmaking: Bringing suppliers and buyers together (e. g., secondary raw material trading platforms, digital platforms for product-service systems and sharing models)
	Lower transaction costs through platforms that offer rapid overviews of potential business partners
Co-creation of new circular solutions	Foster collaborative knowledge sharing and innovation, including through open-source solutions
Dematerialization through virtualization of value propositions	
Enable "product-as-a-service" offerings	Dematerialization of value propositions through "product-as-a-service" services (e. g., cloud computing)
Integrate functions into existing products	Dematerialization of value propositions by integrating functions into a (digital) product for which a separate product was previously required (e. g. flashlight function in a smartphone)
Empower consumers and employees in the transition to a circular economy	
Strengthening consumers' role	Support informed purchase decisions with details on product lifespan, reparability and ecological footprint
	Provide consumers the know-how to take care of the product and conduct routine maintenance (e. g., maintenance and repair instructions, user guidance)
	Facilitate platforms for shared use of privately owned products (e. g., community-based sharing initiatives)
Empower employees in the transition to a circular economy	Promote employee "re-skilling" through digital learning tools
	Provide augmented reality support for on-site repair work, offering expert guidance to semi-skilled workers

Source: Future Impacts / Bertelsmann Stiftung

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Clearly, this overview is not meant to capture every digital application in the circular economy – it focuses solely on those that emerged from our thematic analysis. For example, Berg et al. (2024) pinpoint additional functions related to recycling and end-of-life recovery, such as AI-driven material identification and sorting, robotic disassembly and optimized incineration processes. Moreover, as technology continues to advance – especially in tandem with artificial intelligence – we can expect new digital applications and leverage points to emerge in the coming years.

Finally, it's important to note that digital devices and their components pose significant challenges for the circular economy. Many are designed without repairability in mind, are discarded prematurely and robust recycling options exist only in niche areas

Conclusion: Potentials of transformation to a circular economy in Germany and Europe – a new model for our economy and society?

The global population is projected to approach 10 billion by 2050, while an expanding middle class with shifting consumption patterns is fueling a surge in resource demand. At the same time, global competition for finite and renewable raw materials is intensifying. As emerging economies accelerate, their rising resource needs not only boost local demand but also reshape – and sometimes erode – the export prospects of formerly dominant industrial nations, a trend already painfully evident in Germany. Domestically, markets in Germany and Europe face additional pressure from an aging, shrinking population and widespread market saturation. Other challenges abound. The stark impacts of human-induced climate change demand a rapid reduction in greenhouse gas emissions, and geopolitical instability further complicates the landscape. The labor market is also in flux, with workers in the digital gig and platform economy – vital to sharing initiatives in the circular economy – often finding themselves in precarious positions. Meanwhile, the rapid pace of digitalization and advances in artificial intelligence are reshaping industries, leaving both the economy and society to grapple with multiple, interlinked challenges.

The circular economy as a strategic response to economic challenges

Our analysis of current studies shows that when seen as more than just recycling, the circular economy offers a range of levers and solutions to address these issues. In particular, a circular economy can:

- enhance resource security By recovering raw materials through recycling and extending the lifespan of products, components and materials;
- create new value and employment opportunities by offering services in the domestic market and
- boost climate protection efforts by reducing resource consumption and cutting the energy-intensive processes of raw material extraction, processing and manufacturing.

Yet one point remains clear: while climate protection is firmly embedded in the minds of policymakers and many strategies, the circular economy is still often seen through a technocentric lens focused mainly on end-of-life product management. In reality, the circular economy should be viewed as an evolving, multilayered goal. By advancing even one dimension – such as improving recycling rates – we can unlock broader opportunities to reduce raw material dependency, strengthen climate action and pave the way toward a more socially just economic system.

Future challenges and action priorities

The four thematic areas presented in this paper are defined by specific future challenges in the transition to a circular economy, as well as by the corresponding action priorities that can drive this change. Table 3 summarizes these for each thematic area.

TABLE 3: **Future challenges in transitioning to a circular economy: A summary of findings across four thematic areas**

Future challenges in transitioning to a circular economy	Action priorities
More than recycling	
The need to reduce dependence on critical raw materials and minimize supply chain risks	Foster technological innovations to substitute critical raw materials
	Encourage product designs that facilitate efficient recycling
Managing the flow of products and materials across global value chains	Leverage digital data transparency to inform evidence-based decisions on potential resource conservation and the rollout of circular economy initiatives
The use of secondary raw materials often carries a price premium	Enact regulations that internalize environmental costs and offer monetary incentives and so on
Circular bioeconomy	
Shifting toward sustainable practices in agriculture and forestry	Process residual streams in biorefineries to replace petrochemical base chemicals
Capturing CO_2 in agriculture, forestry and natural habitats (e. g., peatlands)	Use digital land-use mapping to identify and unlock carbon storage potential
Food waste	Spark a cultural shift toward sustainable diets, harness digital analytics for long-term demand forecasting, streamline food logistics, etc.
Designing circular offerings	
Developing products and services for the circular economy (beyond traditional eco-design)	Deploy digital tools to model and assess diverse usage scenarios and support platforms for product-service systems in the circular economy
Circular models remain niche, scaling them is challenging	Standardize processes to build trust among stakeholder coalitions in the value chain
	Cultivate a culture of collaborative value creation and business development
Empower consumers to drive success of circular business models	Encourage changes in consumer behavior to support circular practices Enable cultural change by using digital decision aids that guide product selection, usage, repair and recycling
Ethical orientation	
Define the circular economy with social and ethical dimensions	Foster transdisciplinary dialogue to shape societal requirements and solutions;
	ensure inclusive, participatory decision-making
Build broad support for the transition that mitigates resistance	Invest in workforce education,
	social safety nets for low-income households,
	attractive job offers, information and practical incentives
Risk of adverse effects, particularly in the Global South	Position the circular economy as a catalyst for positive development in the Global South,
	backed by international and multilateral cooperation

Source: Future Impacts / Bertelsmann Stiftung

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TABLE 4: **Core functions of digitalization in the transition to a circular economy**

Core functions of digitalization for a circular economy	Digitalization applications
Build an information base that provides data on products, components and materials to support circular resource management, achieve resource efficiency and craft compelling value propositions	Provide material and product data (product passports)
	Provide information on the availability and quality of (secondary) raw materials
	Capture circularity, ensure transparency
	Learning from data to address knowledge gaps
Bringing together and coordinating stakeholders in circular economy networks and innovative business models	Enable effective stakeholder coordination
	Co-creation of new circular solutions
Dematerialization through virtualization of value propositions	Enable "product-as-a-service" offerings
	Integrate functions into existing products
Empower consumers and employees in the transition to a circular economy	Strengthening consumers' role
	Empower employees in the transition to a circular economy

Source: Future Impacts / Bertelsmann Stiftung

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A look across the thematic areas highlights the vast potential still untapped in achieving a fully realized circular economy. While the debate in Germany has largely centered on technology and recycling, European publications and policy initiatives are signaling a shift toward a broader view of the circular economy as a new socioeconomic model. Three key factors emerge as critical to advancing this transition. First, a cultural shift is needed – one that encourages collaborative partnerships among businesses and drives changes in consumer behavior. Second, we must unleash a wave of innovation through fresh ideas, bold approaches and radically reimagined offerings that can transform value propositions and bring alternative solutions to market. Third, digitalization stands out as a linchpin across all thematic areas, serving as a powerful enabler to scale circular solutions and seamlessly connect providers, consumers and intermediaries.

Digitalization as a key enabler of the circular economy

Our review of the literature identifies four core functions of digitalization that will be instrumental in driving the progress necessary for a robust circular economy (see Table 4).

Outlook

Our review of the literature and the thematic areas identified shows that the circular economy isn't a silver bullet for the broad range of economic and societal challenges we face, and that numerous obstacles still remain. At the same time, it's clear that the circular economy can make a significant contribution to addressing both national and global challenges – especially in securing supply chains and critical raw materials amid rising geopolitical uncertainty. Key levers have already been identified, and a variety of niche solutions are proving successful in the market.

Appendix

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Selection of publications

For our meta-analysis of circular economy concepts, we identified more than 50 publications, reports and academic articles – the "longlist" – that help illuminate current circular economy frameworks. We applied the following criteria:

- **Timeliness:** Works published in the last five years (since 2019)
- **Geographic focus:** Emphasis on Europe and its regions, with select global reports included for context.
- **Institutional diversity:** Contributions from a broad spectrum of sources, including government and public sector bodies, companies, NGOs, civil society, think tanks, academic institutions and foundations.
- **Evidence-based:** Publications that are grounded in robust data and analysis.
- **Forward-looking:** Consideration of emerging trends and future developments.
- **Length:** A minimum length of 15 pages.

From this longlist, we selected 20 publications that best capture the diversity of circular economy concepts (see Table 5). The focus was on analyses that offer a comprehensive overview of European approaches and provide a critical assessment of their content. Additionally, we included works from key figures in the European and German circular economy debate. A synthesis of these sources allowed us to distill the differences among the concepts into the thematic areas presented in this report.

TABLE 5: **Overview of publications included in the meta-analysis**

No.	Author / Title	Geographical emphasis	Type of institution	Type of publication
1	**Acatech** (2019). *Deutschland auf dem Weg zur Circular Economy – Erkenntnisse aus europäischen Strategien* (Vorstudie)	Europe	Academic, think tank	Report
2	**Agora Industrie** (2023).*Resilienter Klimaschutz durch eine zirkuläre Wirtschaft: Perspektiven und Potenziale für energieintensive Grundstoffindustrien*	Germany	Think tank	Report
3	**Baekgaard et al.** (2024).*The technocentric consensus: a discourse network analysis of the European circular economy debate*	Europe	Academic	Academic journal article
4	**Berg et al.** (2024). *Auf dem Weg in die digitale zirkuläre Wirtschaft*	Germany / NRW	Academic	Report
5	**Böckel et al.** (2022). *Mythen der Circular Economy*	Germany and beyond	Academic, foundation	Anthology
6	**Fraunhofer-Gesellschaft** (2023).*Circular Bioeconomy for Germany*	Germany	Academic	Report
7	**Calisto Friant et al.** (2021). *Analysing European Union circular economy policies: words versus actions*	Europe	Academic	Academic journal article
8	**Bahn-Walkowiak et al.** (2019).*Overview report on definition and concept of the Circular Economy in a European Perspective*	Europe	Academic	Report
9	**Circle Economy** (2024). *The Circularity Gap Report 2024*	Global	Foundation, management consultancy	Report
10	**Circular Cities Declaration** (2024). *Circular Cities Declaration 2024.*	Europe	Public sector / Municipal network	Report
11	**Econsense** (2021). *Germany's Transition to a Circular Economy*	Germany	Corporate network	Report
12	**EEA** (2024). *Accelerating the Circular Economy in Europe*	Europe	Public sector / EU institution	Report
13	**Ellen MacArthur Foundation** (2024). B*uilding prosperity*	Europe	Foundation	Report
14	**Hedberg and Sipka** (2020). *The Circular Economy: Going Digital*	Europe	Think tank	Report
15	**Institut National de l'Économie Circulaire** (2020). *Major Circular Economy Networks in Europe*	Europe	Multi-stakeholder network	Report
16	**Kirchherr et al.** (2023). *Conceptualizing the Circular Economy*	Global	Academic	Academic journal article
17	**De Pascale et al.** (2023). *The Circular Economy Implementation at EU Level*	Europe	Academic	Academic journal article
18	**Pinyol Alberich** (2022). *Motives of the European Union Member States to Adopt Circular Economy Strategies*	Europe	Academic	Academic journal article
19	**UNIDO** (2024). *National Circular Economy Stocktake for 2024*	Global	Public sector / UN institution	Report
20	**WEF** (2023). *Circular Transformation of Industries*	Global	Multi-stakeholder network, management consultancy, academic	Report

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