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RESEARCH ARTICLE

# From Carbon Footprint to Circular Brainprint: Advancing Behavioral Foundations of the Circular Economy

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## Abstract

This conceptual article introduces the "circular brainprint," a framework that links upstream mindset conditions to the concrete uptake of circular practices across the 10R. We address a clear gap: existing work measures downstream outcomes (footprints/handprints) or offers generic behavioral tools, but lacks a map from identifiable antecedents—biases, ownership frames, norms, trust, skills, and access—to adoption of repair, reuse, sharing, and product-service systems. We define the circular brainprint as the cognitive–social–educational infrastructure that raises the probability of these choices and makes them persistent. Building on a structured narrative synthesis across psychology, behavioral economics, and sustainability education, the article derives testable propositions that connect micro-mechanisms and meso-level supports to specific circular options. Education features as a lever that reconfigures antecedents—building skills and perceived control, shifting descriptive/injunctive norms, and strengthening provider trust—rather than as awareness alone. We outline measurable indicators (e.g., repair/reuse rates, refurbished share, PSS uptake) that operationalize the brainprint and enable policy design.

**Keywords** Circular Economy · Circular Brainprint · Sustainable Consumption Behaviour · Education for Sustainable Development · Behavioural Antecedents

## 1. Introduction

The circular economy is increasingly recognized as a key solution to global environmental challenges, particularly in reducing carbon emissions (Gómez-Prado et al., 2022). This economic model aims to optimize resource efficiency, minimize waste, extend product life, and decrease the use of raw materials and greenhouse gas emissions (MacArthur, 2013). It is based on the principles of reduce, reuse, and recycle (the 3Rs) – extended later to the 10Rs (Potting et al., 2017) –, which are essential for decoupling economic growth from resource depletion and environmental harm (Heshmati, 2017; Hachaichi & Bourdin, 2021).

The circular economy is thus positioned as an effective decarbonization strategy, particularly in sectors such as construction, industry, and manufactured goods, where greenhouse gas emissions and resource consumption are significant (Calle Müller et al., 2024). In the European Union, for example, the construction sector is responsible for almost a third of annual greenhouse gas emissions. The integration of circular practices, such as the reuse of materials, can reduce these emissions by up to 99% per functional unit (Gallego-Schmid et al., 2020). Furthermore, the large-scale implementation of the circular economy

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requires a profound transformation of value chains and production modes (Lopes de Sousa Jabbour et al., 2018). The success of this transition also depends on adequate regulation and strong political will to encourage the adoption of these practices, particularly in the energy and industrial sectors (Kirchherr et al., 2018). While sustainability efforts often focus on minimizing environmental impact, the circular economy goes a step further by offering actionable, system-based solutions that prioritize closing material loops, fostering resource regeneration, and transforming production-consumption patterns. These characteristics make the circular economy a compelling framework and also a practical roadmap for achieving measurable environmental and economic benefits.

Although technological advances have provided solutions to make production and consumption processes more efficient, they are not sufficient on their own to achieve a significant reduction in carbon emissions. Current consumption and production behaviors, rooted in a linear "extract, manufacture, throw away" model, pose a major obstacle to the transition to a circular economy (Camacho-Otero et al., 2018). It is therefore imperative to change these behaviors, both individually and collectively, to align practices with sustainability goals (Maitre-Ekern & Dalhammar, 2019). We therefore frame the problem in terms of antecedents—the upstream conditions that shape whether repair, reuse, sharing, or product-service options are actually chosen.

The implementation of circular models depends on consumers extending product lifetimes through repair, sharing, and reuse, and on complementary behaviors that support upstream producer efforts (Zibell et al., 2021; Macklin & Kaufman, 2023). New propositions such as product-service systems and rental schemes face behavioral frictions tied to ownership attachment and the "consumption work" they impose—new routines, maintenance responsibilities, and unfamiliar decision sequences—which many perceive as complex and burdensome (Daae et al., 2018; Hobson et al., 2021; Lane et al., 2024; Fabiana et al., 2024). Beyond these costs, evidence on psychological motivations shows that altruism is neither necessary nor sufficient to explain uptake. A systematic review identifies environmental literacy, perceived financial benefits, and entrenched habits as central drivers and barriers alongside environmental beliefs (Zimmerman et al., 2024). Empirical studies of leasing models point to value and convenience as primary determinants, with environmental aspects playing a minor role in decisions (Asif et al., 2023). Trusted relationships with providers also matter: prior ties significantly facilitate adoption in circular food provisioning (Borrello et al., 2020). Against this backdrop, findings that foreground "pure altruism" should be interpreted narrowly: for instance, de Morais et al. (2021) compare only three factors, so their conclusion ranks altruism above competitive altruism/status within a limited design and does not generalize beyond those tested constructs.

Furthermore, commitment to the circular economy cannot be fully realized without understanding and addressing consumers' psychological motivations. Motivations extend beyond altruistic values and encompass cognitive, economic, and relational dimensions that influence individual engagement. De Morais et al. (2021) has revealed that pure altruism is one of the motivations for adopting green behaviors, while factors such as the need for social status play a lesser role. A broader review of the literature reveals a more complex picture. Zimmerman et al. (2024), in a systematic review, identify environmental literacy, financial considerations, and established consumption habits as central drivers and barriers. Asif et al. (2023) observe that decisions to engage in leasing models primarily reflect perceptions of value and convenience rather than environmental concerns. Borrello et al. (2020) also highlight the importance of prior relationships with providers of circular services in facilitating adoption. These frictions indicate that information is insufficient unless the underlying antecedents—habits and biases, ownership frames, norms and trust, and skills/access—are deliberately reconfigured.

Despite extensive work on sustainable behavior, the literature still lacks a construct that links concrete circular options to their enabling cognitive and social conditions. Existing approaches describe impacts (footprint) or avoided harms (handprint), or they propose generic nudges and incentives. Moreover, what remains under-specified is the micro-to-meso pathway that turns status-quo bias, psychological ownership, trust, and skills into the adoption of circular practices (Neramballi et al., 2024). The circular brainprint addresses that pathway and states testable propositions; for example, higher trust in certified repair predicts higher repair rates despite small cost disadvantages (Hartley et al., 2022; Janssens et al., 2021).The circular brainprint advances this landscape with a falsifiable claim: identifiable cognitive, social, and educational preconditions raise the probability of repair, reuse, sharing, and product-service uptake, net of prices and

information. This article targets that gap with a focus on mindset conditions that convert intention into adoption of circular options. More specifically, it highlights the importance of education and training for citizens, professionals, and elected representatives in transforming mindsets, knowledge, and behaviors in favor of a circular, low-carbon economy. Education for sustainable development (ESD) has proven effective in raising awareness and mobilizing individuals around ecological issues, particularly through structured programs that encompass resource management, waste reduction, and more sustainable energy practices (Scalabrino et al., 2022).

This article proposes the circular brainprint as a distinct conceptual lens. The lens isolates antecedents that standard behavioral-economics accounts treat as residual or context noise and ties them to specific circular choices rather than to generic sustainability attitudes. The article seeks to contribute to the growing debate on behavioral aspects of circular economy by proposing an original conceptual framework: the "circular brainprint." This concept builds upon existing literature on cognitive biases, cultural norms, and sustainable education, and brings a novel perspective by linking these elements within a unified approach to mindset transformation. While previous research has emphasized psychological barriers or educational interventions in isolation, few studies have offered a structured synthesis of the cognitive, institutional, and cultural levers required to foster circular behaviors. While footprint measures what results from behavior, handprint registers benefits from actions, circular brainprint specifies the upstream conditions that make circular actions likely and persistent. This integrative positioning constitutes the core contribution of this article and seeks to fill a gap identified in recent reviews of circular behavior research (Vidal-Ayuso et al., 2023). The concept of the circular brainprint, is based on the idea that fostering the transition to a circular economy requires changing thinking patterns. This involves forming a collective mindset oriented toward sustainability, reuse, repair, and minimizing extracted resources (Davidescu et al., 2020). When individuals are trained and empowered on environmental issues, they can significantly reduce their carbon footprint and effectively contribute to the circular transition (Décamps et al., 2017; Lizana et al., 2021).

This article is a conceptual contribution anchored in a structured narrative review across psychology, behavioral economics, and sustainability education. The goal is theory development rather than exhaustive coverage; therefore, we do not follow systematic-review protocols. The review draws on Web of Science and Scopus over 2000–2025, with targeted citation chains for seminal work; inclusion requires peer-reviewed sources that link antecedents to identifiable circular practices, while purely technical papers without a behavioral or educational angle remain outside the scope. One question guide the synthesis: How do cognitive, social and educational antecedents raise the probability of adopting identifiable circular options (across the 10R), and how can this be captured as a measurable "circular brainprint"?

Our literature integration follows a layered synthesis that underpins the derivation of the circular brainprint: reviews on circular consumption (Camacho-Otero et al., 2018; Vidal-Ayuso et al., 2023; Zimmerman et al., 2024) establish the behavioral problem space; studies on biases and ownership specify micro-mechanisms (Singh & Giacosa, 2019; Rogers, 2021); work on organizational and institutional barriers defines meso-level constraints (Rizos et al., 2016; Hina et al., 2022; Hartley et al., 2022); and education research provides levers to modify antecedents (Décamps et al., 2017; Williams et al., 2017; Melles & Paixao-Barradas, 2019; Décamps et al., 2021; Sukiennik et al., 2021).

The remainder of this article is structured as follows. Section 2 organises the literature around antecedents, detailing the cognitive (habits, inertia, ownership, risk) and social–cultural (norms, trust, peer effects, market routines) mechanisms and showing how these interact to create adoption frictions. Section 3 analyses education as antecedent reconfiguration, specifying which curricula, pedagogies, and skills pipelines shift skills/efficacy, norms, and provider trust, and how to measure both antecedents and outcomes. Section 4 integrates these threads into the circular brainprint mechanism, mapping upstream conditions to 10R adoption families and identifying policy and design levers that modify each antecedent. The conclusion synthesises implications and outlines a testable research agenda for circular behaviour and education.

# 2. Cognitive and Social Antecedents of Circular Adoption

A wide range of actors plays a role in shaping behavioral change within the circular transition. These include individuals, who act as consumers, users, or citizens; businesses, which function as producers, employers, and innovators; and public institutions, which influence behaviors through regulations, incentives, and education. Understanding the specific drivers and constraints each group faces is essential to identifying the levers that can accelerate circular practices. We structure the review from micro to meso: cognitive mechanisms and social influence at the individual level, then organizational and sectoral frictions, and finally norms and culture shaping acceptance of circular options.

## 2.1. Cognitive antecedents: habits, inertia, ownership & risk appraisals

Cognitive antecedents lower the baseline likelihood of circular choices. Habits and cognitive inertia keep individuals and organisations anchored to familiar routines; changing course requires more than information—it requires a reframing of value, risk, and control. Status-quo and loss-aversion biases, comfort with established practices, and ownership framing raise perceived switching costs and make repair, reuse, or access-based models feel risky or inconvenient (Werning & Spinler, 2020; Gonella et al., 2024; Musova et al., 2025). Cognitive inertia often manifests as skepticism toward the efficacy or practicality of circular economy solutions, particularly in sectors with longstanding linear business models. These models, deeply embedded in economic systems, demand technical and operational adjustments as well as a cultural transformation in the way value is perceived, created, and sustained (Hina et al., 2022; Grafström & Aasma, 2021). The circular economy offers a distinctive framework for addressing behavioral barriers by linking systemic change with clear, tangible actions at both the individual and organizational levels. Unlike broader environmental sustainability initiatives, which often rely on generalized awareness, the circular economy fosters change by integrating specific, economically viable practices, such as repair, reuse, and closed-loop production, that appeal to both ecological and financial incentives. Some authors stress intrinsic motivation and ethical engagement (de Morais et al., 2021), while others point to structural conditions and institutional incentives as the primary levers (Rizos et al., 2016). We acknowledge this tension and propose that these factors interact in complex ways rather than operating in isolation.

Organizational actors, particularly SMEs, face specific structural and financial constraints that reinforce behavioral resistance. In sectors where the perceived costs of change—whether in time, effort, or financial investment—are high, this resistance becomes even more pronounced (Kirchherr et al., 2018 ; Saarinen, A., & Aarikka-Stenroos, 2023). For instance, small and medium-sized enterprises (SMEs) often acknowledge the theoretical benefits of transitioning to circular practices but face practical challenges that hinder implementation. The initial costs associated with adopting new technologies, retraining staff, or redesigning production lines are often perceived as disproportionately high relative to the potential benefits, particularly among SMEs operating under tight financial constraints. Even when objective long-term advantages appear evident, uncertainty about returns and a subjective overestimation of risks can discourage action. A lack of access to financial support or technical expertise reinforces this perception of vulnerability and fuels a sense of insecurity, which contributes to a vicious cycle of inaction and resistance (Rizos et al., 2016; Kirchherr et al., 2018). Recent studies have nuanced these difficulties, showing that while SMEs may express willingness to adopt circular models, their limited capacity for experimentation and risk-taking plays a decisive role (Gonella et al., 2024). These constraints call for specific support mechanisms that go beyond informational tools. Taken together, these contributions indicate that generic "awareness" is insufficient unless biases, ownership perceptions, and risk appraisals are tackled in context (Singh & Giacosa, 2019; Rogers, 2021). This motivates a mechanism-first lens that later informs our brainprint mapping to concrete 10R adoptions (Vidal-Ayuso et al., 2023; Muranko et al., 2018). This micro-level profile sets the first layer of the brainprint.

## 2.2. Social & cultural antecedents: norms, trust, peer effects, market routines

Beyond individual cognition, meso-level antecedents—descriptive and injunctive norms, trust in providers, peer effects, and entrenched market routines—set the social "permission structure" for circular choices. When second-hand or repair is seen as atypical, risky, or low-status, and when supply-side routines signal linear defaults, even motivated individuals hesitate to adopt reuse or repair. In practice, misconceptions about quality/durability dampen demand (Grafström & Aasma, 2021), peer norms shape acceptability (Camacho-Otero et al., 2018; Borrello et al., 2020), and provider trust conditions uptake of access-based models (Hina et al., 2022; Macklin & Kaufman, 2023). Similarly, businesses may hesitate to depart from linear models due to a deeply ingrained reliance on conventional production and consumption practices (Hina et al., 2022). This reluctance can be particularly strong in industries where linear systems have been profitable and culturally normalized over decades (Grafström & Aasma, 2021). Although many authors emphasize consumer-related limitations, some contributions highlight the role of producers, intermediaries, and retailers in reinforcing linear habits through supply-side signals (Hina et al., 2022). These perspectives show that cultural barriers are both individual and structural, as they stem from routines, norms, and established commercial practices.

These cultural and behavioral barriers are often intensified by a lack of awareness and incentives to embrace circular practices (Gonella et al., 2024). For example, despite growing evidence of the environmental and economic benefits of the circular economy, many businesses and consumers remain unaware of the practical advantages or potential cost savings of these models (Van Langen et al., 2021). This lack of awareness, coupled with the absence of compelling incentives, significantly hinders the widespread adoption of circular approaches (Kirchherr et al., 2018). Furthermore, social norms and peer behaviors heavily influence consumption decisions, perpetuating resistance to new models even when they offer clear advantages. While the pursuit of social status may not represent a primary driver for most individuals, the desire to align with prevailing norms and avoid social disapproval exerts a significant influence (Macklin & Kaufman, 2023; Zibell et al., 2021). In this sense, social conformity operates as a distinct mechanism from status-seeking, as it reflects the tendency to adopt behaviors perceived as typical or acceptable within a reference group, rather than an aspiration to enhance one's relative standing (Camacho-Otero et al., 2018; Borrello et al., 2020). These meso-level forces constitute the second layer of the brainprint and condition whether motivated individuals actually adopt circular options.

## 2.3. Mechanism notes — How cognitive, cultural and behavioral antecedents translate into adoption frictions

Adoption frictions emerge when cognitive and social mechanisms compound: status-quo and loss-aversion biases, ownership framing, and learning costs dampen willingness to switch, while low provider trust and prevailing norms amplify that reluctance. This interaction explains why information or awareness alone rarely shifts behaviour. In particular, status-quo bias leads consumers and organisations to avoid new practices—even when objectively beneficial (Maitre-Ekern & Dalhammar, 2019)—and cognitive biases more broadly operate as psychological barriers to change (Jabbour, 2024; Musova et al., 2025). Similarly, the tendency to underestimate future benefits while overestimating immediate costs—known as hyperbolic discounting—deters individuals and businesses from investing in circular solutions that promise long-term advantages (Singh & Giacosa, 2018). Circular practices, such as product-as-a-service models or material reuse systems, are often viewed as too complex, abstract, or distant from current norms to justify the effort required for their adoption (Neramballi et al., 2024). However, recent work has questioned whether these biases alone can explain reluctance. Some studies point to learning costs, trust in providers, and perceived identity threats as equally decisive variables (Hartley et al., 2022; Rogers, 2021). An illustrative example of these cognitive biases in action is the case of Electrolux's "pay-per-wash" service in Sweden. Despite offering energy-efficient washing machines with maintenance and upgrades included, the initiative failed to gain traction (Waddilove, & Charnley, 2015). Consumers were reluctant to adopt the service due to

concerns over losing ownership, potential cost increases, and service interruptions, which reflected status quo bias and loss aversion. This psychological discomfort often overrides perceived environmental or financial benefits and demonstrates that behavioral resistance emerges from a combination of rational calculation, affective responses, and symbolic considerations.

In addition, perceptions of ownership significantly influence behavioral resistance (Rogers, 2021). Many consumers associate leased or shared ownership models with uncertainty and a perceived loss of control. The potential for changes in conditions, rising costs, or service interruptions—often cited in product-as-a-service systems—can discourage adoption. This psychological discomfort can override environmental or financial benefits, further emphasizing the need to align business models with user trust and transparency (Singh & Giacosa, 2018).

Cultural perceptions also play a significant role in shaping resistance to circular economy practices (Beaurain et al., 2023). For instance, in some industries like technical textiles, consumers may associate circular products with inferior quality or reduced performance, even when these products meet or exceed traditional standards (Hartley et al., 2022). Such perceptions hinder the adoption of circular practices, particularly when coupled with a lack of information or awareness about sustainable design options. In short, antecedents interact: cognitive frictions and social signals compound, which explains why awareness campaigns underperform without changes to skills, trust, and norms.

### 2.4. Mindset transformation as reconfiguration of antecedents

Mindset transformation works by reconfiguring antecedents. Reframed mental models shift perceptions of value, control, and ownership, weakening cognitive inertia and loss aversion (Rogers, 2021). A sufficiency- and stewardship-oriented mindset increases perceived behavioural control (skills/efficacy), builds trust in services, and reframes psychological ownership from objects to outcomes—thereby making repair, reuse, and sharing feel acceptable and worthwhile (Singh & Giacosa, 2019; Hobson et al., 2021). In short, mindset change alters the cognitive and social inputs that previously suppressed adoption, raising the probability of 10R-aligned choices. This transformation also supports the capacity of individuals to accept the active role demanded by product-service systems and other circular models, which require continuous "consumption work" and adaptive behaviors (Lane et al., 2024; Macklin & Kaufman, 2023). In addition, a redefined mindset can reduce the perceived complexity of circular practices by integrating them into personal identities and social norms, thereby facilitating acceptance and trust (Camacho-Otero et al., 2018). Potting et al. (2017) underline that innovation in product chains must be accompanied by cultural shifts in how consumers evaluate sufficiency and resource efficiency, because technical solutions alone rarely suffice to trigger systemic change. In this sense, mindset change operates as an enabling condition that strengthens the capacity of individuals and organizations to reinterpret risks, recalibrate expectations, and reconfigure consumption routines in line with circular principles. Mindset change is thus not an abstract ideal but a reconfiguration of antecedents that raises the base probability of 10R-aligned choices.

## 3. Education as Antecedent Reconfiguration

### 3.1. Education as reconfiguration of antecedents (what education changes and how)

Education functions as an antecedent reconfiguration tool. It builds skills and perceived behavioural control via hands-on repair and design modules; it shifts descriptive and injunctive norms through collaborative, community-embedded projects; and it strengthens trust in circular services with certification, transparency, and quality signals. As these inputs change, the likelihood of repair, reuse, and access-based models rises—an effect that pure information campaigns rarely achieve (Décamps et al., 2017; Melles & Paixao-Barradas, 2019; Décamps et al., 2021; Sukiennik et al., 2021). To be transformative, these mechanisms should operate

across the learning lifecycle—from early schooling to higher/vocational education and professional upskilling—so that competencies, norms, and trust accumulate over time. The integration of circular economy concepts into educational programs at all these levels represents a critical step forward (Bonnett, 2002; Žalėnienė & Pereira, 2021). Such integration requires curricula that transcend general sustainability goals, focusing instead on methodologies such as life cycle thinking, resource flow analysis, and circular design strategies. These tools equip individuals to grasp and implement circular principles in practical settings, effectively bridging the divide between theoretical understanding and actionable practices. Several authors agree on the formative potential of education, yet their emphases vary. Some stress individual agency and moral responsibility (Bugallo-Rodríguez & Vega-Marcote, 2020), while others highlight institutional embedding and policy support as prerequisites for real behavioral change (Žalėnienė & Pereira, 2021).

Research on education for sustainable development (ESD) demonstrates that initiatives embedded within higher education institutions can (i) lessen the ecological footprint of campuses and (ii) nurture responsible citizens capable of integrating circular economy principles into their personal and professional lives (Bugallo-Rodríguez & Vega-Marcote, 2020). Equally, at the elementary and secondary levels, circular education helps build early awareness and habits aligned with resource stewardship and environmental responsibility (Alarcón et al., 2019; Scalabrino et al., 2022). However, the literature also warns against superficial integration. Without meaningful pedagogical change, curriculum reform risks remaining symbolic. According to Melles & Paixao-Barradas (2019), real transformation requires project-based methods and interdisciplinary framing.

Within the framework of the circular economy, education facilitates a comprehensive understanding of resource loops and fosters collaborative value creation (Williams et al., 2017; Sukiennik et al., 2021). Traditional environmental education often limits itself to raising awareness, whereas circular economy education emphasizes systemic thinking and participatory problem-solving (Muranko et al., 2018; Melles & Paixao-Barradas, 2019). This approach reshapes learners' perspectives and is encouraging them to recognize waste as a resource, production as a cyclical process, and collaboration as a foundation for innovation. While traditional sustainability approaches focus on awareness and responsibility, the circular economy introduces actionable strategies such as repair, reuse, and regeneration—reflecting a higher-order philosophy grounded in regeneration and resilience (Sukiennik et al., 2021).

Interdisciplinary educational practices that include circular economy principles transmit both technical expertise and systemic ethical perspectives. These pedagogical approaches establish clear links between theoretical concepts and real-world applications. Learners gain the capacity to reinterpret production and consumption systems through the lens of resource circularity and long-term sustainability. Systems thinking serves as a foundation for reorienting behaviors and decisions toward ecological resilience and efficiency (Melles & Paixao-Barradas, 2019; Muranko et al., 2018). Educational models based on concrete projects, case-based analysis, and collective design processes foster active involvement. According to Sukiennik et al. (2021), these experiences strengthen learners' motivation to pursue circular solutions across different fields and contexts. Exposure to collaborative formats that include external stakeholders reinforces the acquisition of transversal competencies and promotes a culture of shared responsibility (Williams et al., 2017).

An exemplary model comes from Finland, where the integration of circular economy principles has been achieved through a multi-level alignment of educational strategies with the Sustainable Development Goals (SDGs). This approach ensures that students at various educational stages are exposed to the interconnected aspects of sustainability and the circular economy, positioning Finland as a benchmark for other nations seeking to embed these principles into their educational systems (Sysoiev, 2022).

## 3.2. Curricula & pedagogy (Which antecedents they change)

Curricula and pedagogy should target specific antecedents of circular adoption. Project-based labs and repair/design studios build skills and perceived behavioural control for diagnostics, disassembly, refurbishment, and materials literacy (Kirchherr et al., 2018; Macklin & Kaufman, 2023). Community

partnerships, peer studios, and showcase events reset descriptive and injunctive norms, making reuse and repair visible and typical (Muranko et al., 2018; Sukiennik et al., 2021). Assessment rubrics, recognised certificates, and transparent quality criteria strengthen trust in refurbished goods and service providers (Janssens et al., 2021; Grafström & Aasma, 2021). The persistent shortage of qualified technicians confirms the centrality of the skills pathway and justifies curricular emphasis on repair, remanufacturing, and material recovery. Expected effects include higher repair/reuse rates and greater acceptance of product-service models. This skills gap affects various sectors, from electronics and textiles to construction and industrial maintenance. For example, Macklin and Kaufman (2023) emphasize that the success of circular strategies often depends on the availability of technicians trained in diagnostics, disassembly, and refurbishment, yet vocational training in these areas remains limited in many regions. Moreover, tinkering and informal repair skills—frequently acquired outside formal education—are undervalued despite their strategic relevance for extending product life cycles (Hobson et al., 2021).

Research has demonstrated that preparing students to integrate circular economy principles fosters competencies in resource management, sustainable design, and ecological innovation. These approaches go beyond raising awareness, equipping learners with the tools to actively redesign resource flows and reimagine consumption models. For instance, programs in Mexico have illustrated the effectiveness of combining theoretical instruction with practical, business-case development to operationalize circular thinking in professional contexts (Sanchez et al., 2020). Nevertheless, the literature points to uneven implementation across institutions. Mendoza et al. (2019) underline the difficulty of aligning academic programs with real business needs. Theoretical content remains underutilized if students lack occasions to translate knowledge into decision-making frameworks.

Meanwhile, introducing these concepts at earlier stages of education lays the groundwork for long-term behavioral change. For example, in Chile, elementary school initiatives have incorporated circular economy ideas through “Do It Yourself” (DIY) projects, where students creatively reuse waste materials. Such projects teach children the importance of recycling and resource management while fostering critical thinking and innovation (Alarcón et al., 2019). These examples highlight the potential of applied methods. Yet, transferability depends on national systems, teacher training, and available resources — dimensions that are unevenly discussed in the literature and deserve further investigation.

## 3.3. Skills pipelines and lifelong learning (building efficacy and provider trust)

Skills pipelines and lifelong learning should build efficacy and provider trust beyond initial education. Professional and policy upskilling programmes raise diagnostic, disassembly, refurbishment, and resource-management competencies; recognised credentials and transparent quality standards signal provider reliability to users and clients. These elements reduce perceived risk and increase acceptance of repair, refurbish, and product-service offers (Venn et al., 2022; Janssens et al., 2021; Macklin & Kaufman, 2023). National and regional initiatives—such as Ukraine’s training on waste management, alternative energy, and air/water protection—illustrate how targeted modules translate into deployable expertise and higher confidence in circular services (Sysoiev, 2021). Expected effects include higher repair/reuse rates, greater uptake of refurbished products, and stronger Product-Service System acceptance, especially where credentials are visible and service networks are dense (Kirchherr et al., 2018).

Universities also play a pivotal role in continuing education for professionals. In Belgium’s Limburg region, a study of skills gaps revealed the importance of cross-disciplinary competencies—such as resource optimization and ecological innovation—alongside technical expertise. These findings highlight the necessity of integrating the circular economy into training frameworks, as it offers a structured approach to addressing the complexities of resource management and fostering systemic innovation (Janssens et al., 2021).

### 3.4. Measuring antecedents and outcomes

Measurement must track antecedents and outcomes in tandem. Knowledge tests such as SULITEST capture literacy, yet they miss the mediators that shift behaviour. Program evaluation should include skills/efficacy scales (hands-on diagnostics, repair proficiency), norm salience (descriptive/injunctive norms for reuse/repair), and trust indices in refurbished goods and service providers (Décamps et al., 2021). Outcomes should be recorded with operational metrics: repair rate, reuse/redistribution rate, PSS uptake, refurbish share, time-to-second-life, and effective recycling rate. Useful data sources include course and certification records, warranty and service logs, platform transaction data, and municipal waste streams. Designs that strengthen inference—pre/post cohorts, matched comparisons, or field trials where feasible—link educational inputs to changes in mediators and to adoption across the 10R. This dual focus turns education assessment from knowledge auditing to behavioural impact accounting aligned with the circular brainprint.

The insights gained from such assessments inform the evolution of pedagogical methods, enabling educators to adopt innovative strategies that enhance learning outcomes. These approaches focus on fostering a practical understanding of circular systems, empowering individuals to actively redesign consumption and production patterns. This shift allows for the achievement of goals that surpass the scope of traditional environmental protection. Additionally, these strategies support the monitoring of individual progress and drive continuous improvement in educational systems, ensuring alignment with the evolving demands of the circular economy transition (Melles & Paixao-Barradas, 2019). Yet, as noted by Muranko et al. (2018), such methods require institutional flexibility and investment, which are not guaranteed in all systems. These educational levers explicitly reconfigure antecedents; Section 4 folds them into the circular brainprint mechanism.

## 4. Towards a Circular Brainprint

Building on Sections 2–3, we integrate the mapped antecedents and the educational levers into a single mechanism—the circular brainprint—that links upstream conditions to five families of circular adoption. Behavioral change is essential for enabling the circular economy to achieve its full decarbonizing potential. Technological advances, while necessary, will not suffice to reverse the current trajectory without a profound transformation of mindsets and practices. Unlike broader sustainability goals, the circular economy demands a shift toward specific behaviors and systemic practices that emphasize closing resource loops, fostering reuse, and promoting material regeneration. This requires collective awareness, changes in consumer habits, and collaboration at all levels of society. Behaviors must align with sustainability goals to ensure efficient resource use, reduce waste, and minimize the carbon footprint (Muranko et al., 2018). Building on these threads, the circular brainprint is derived as an integrative construct: it links micro-mechanisms (biases, ownership, trust), meso-structures (skills, access, institutional supports), and educational levers to specific 10R adoption families—going beyond outcome-focused footprints/handprints (Gallego-Schmid et al., 2020; Gómez-Prado et al., 2022) and beyond generic behavioral-economics toolkits (Singh & Giacosa, 2019; Muranko et al., 2018).

The circular brainprint denotes the structured set of cognitive schemas, social norms, and learned skills that raise the likelihood of concrete circular behaviors. The construct differs from ecological footprint and carbon handprint, which register downstream outcomes. It also extends standard behavioral-economics toolkits through an explicit mapping from antecedents (e.g., status-quo bias, psychological ownership, trust, availability of repair skills) to distinct practices (Figure 1). This mapping supports testable predictions and policy design at individual, organizational, and territorial scales. The “brainprint” metaphor signals that the transition to a circular economy requires an intentional redesign of the cognitive patterns that underpin consumption and production decisions. It conveys, on one hand, that mindsets leave a measurable imprint on material outcomes, similar to the way a carbon footprint reflects aggregate behaviors. On the other hand, it implies that this imprint can undergo deliberate transformation through education, policy interventions, and collective learning processes. Compared with ecological footprint and carbon handprint, which measure downstream results (Gallego-Schmid et al., 2020; Gómez-Prado et al., 2022), the circular brainprint defines

upstream conditions and supports policy design through explicit indicators such as repair rates, reuse rates, and Product-Service System uptake.

Figure 1 illustrates how antecedents combine into a circular brainprint and channel toward five adoption families across the 10R. Three blocks on the left set out cognitive, social and educational antecedents (status quo bias, loss aversion, norms, trust, repair skills, access to service). These inputs form the circular brainprint at the center. Five adoption boxes on the right represent Refuse/Reduce/Rethink; Reuse/Redistribute; Repair/Refurbish; Remanufacture/Repurpose; Recycle/Recover. A policy-and-design bar at the top lists defaults, warranties, service quality, price tools, education modules, trust safeguards, and access to repair.

Hence, the "circular brainprint" concept refers to aligning mindsets with the principles of the circular economy to strengthen environmental awareness and collaboration around resource management. While decarbonization is a central objective, achieving a circular economy also demands a zero-waste mindset. Current estimates suggest that less than 10% of all products ever produced are recycled, which underscore the urgency of behavioral transformation toward full material recovery. The concept of a "circular brainprint" highlights the actionable nature of the circular economy as a framework for systemic transformation. Unlike traditional sustainability approaches, which often focus on reducing harm, the circular economy emphasizes creating closed-loop systems and maximizing resource value, making it a more direct and compelling driver of behavioral and economic shifts. We postulate that a shift in mindsets is a prerequisite for transforming the economy toward decarbonization and the creation of territorial circular ecosystems (Bourdin & Torre, 2024). The collaborative approach plays a key role in adopting this mental shift by facilitating the sharing of resources (tangible and intangible) and the exchange of knowledge among stakeholders.

To promote this shift in mentality on a large scale, it is key that stakeholders—whether educational, professional, or political—invest in education and training. These interventions should aim to raise public awareness, promote pro-environmental behaviors, and create incentives for transitioning to a circular economy. Additionally, incorporating the circular economy into the decision-making processes of companies and local authorities would embed these practices in organizations' long-term strategies (Williams et al., 2017).

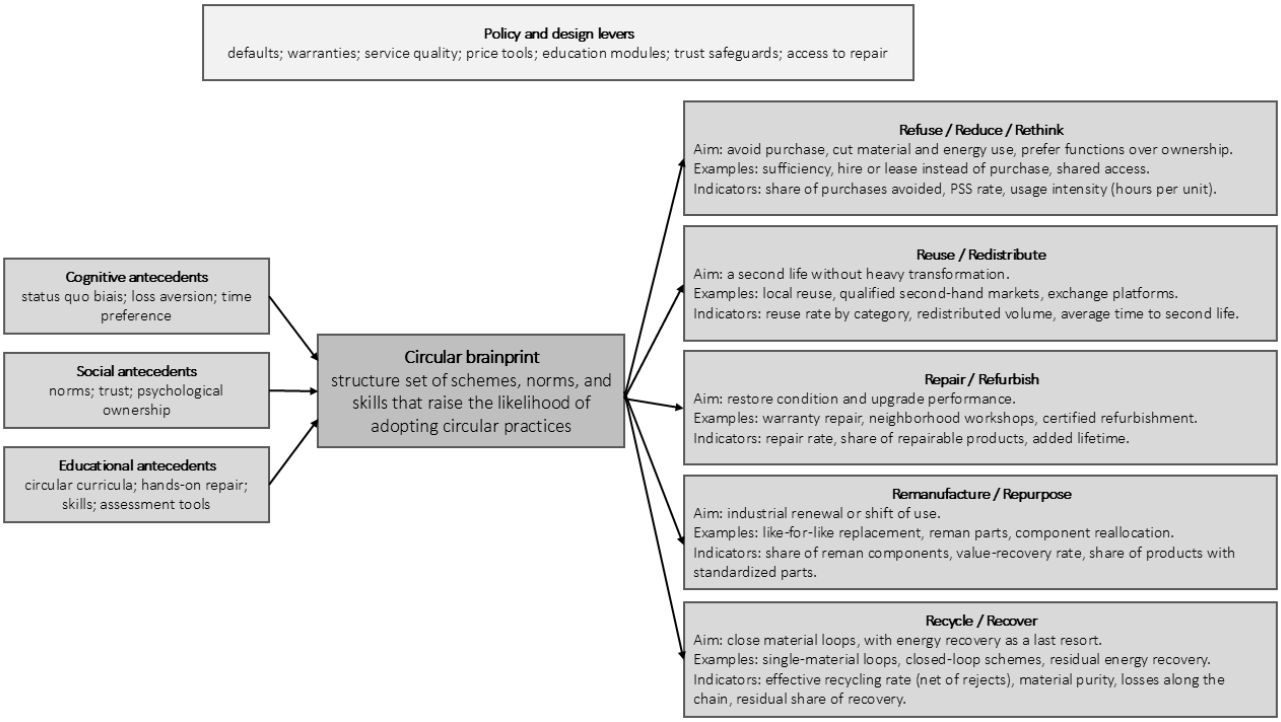


**Figure 1**. Circular brainprint: linking antecedents to five adoption families

# 5. Conclusion

This article has introduced the concept of the circular brainprint as a novel framework to highlight the centrality of behavioral transformation in the transition toward a circular, low-carbon economy. While technological innovations and regulatory mechanisms remain essential enablers of circularity, they cannot fully succeed without a concurrent and deep-seated evolution in how individuals, organizations, and societies think, act, and make decisions. Our contribution is a mechanism-first account: the circular brainprint links identifiable antecedents—biases, ownership frames, norms, trust, skills, and access—to specific adoption families across the 10R. The aim is alignment between cognitive processes and circular principles such as reuse, repair, sufficiency, and shared stewardship.

Through a synthesis of literature drawn from psychology, behavioral economics, and education for sustainable development, this article has highlighted that cultural inertia, cognitive biases, and social norms often constitute overlooked yet formidable barriers to circular behavior. To overcome these obstacles, systemic change must be supported by targeted interventions across all layers of society—especially within education systems. Embedding circular economy principles in curricula from primary to higher education, along with ongoing professional training, appears decisive to cultivating a new generation of citizens and professionals equipped to engage with complexity, challenge linear habits, and co-create resilient economic models. The distinct contribution of this article lies in specifying the circular brainprint as a theoretical construct that bridges psychological, social, and educational insights. Unlike previous approaches, it provides a falsifiable set of propositions on how mindsets become measurable antecedents of circular practices. This positions the article not as a general commentary, but as a step toward a testable research agenda on the behavioral foundations of circularity.

The synthesis across psychology, behavioral economics, and sustainability education shows that cultural inertia, cognitive biases, and social norms block circular choices. Education enters this picture as an instrument that reconfigures antecedents rather than as awareness alone. It builds skills and perceived control, shifts descriptive and injunctive norms, and strengthens trust through certification and quality signals. These levers translate into observable indicators—repair and reuse rates, refurbished share, and PSS uptake—which anchor the brainprint in measurable outcomes. In this sense, the brainprint complements footprint and handprint metrics with an upstream, testable map from mindset conditions to adoption.

Policy and design follow from this mechanism. Defaults, warranties, access to repair, service quality standards, transparent pricing tools, and targeted education modules alter the antecedents that suppress adoption. Organizations and local authorities can deploy these levers at firm and territorial scale, track the same indicators, and iterate on programs that raise the probability of 10R-aligned behavior.

A research agenda now becomes clear. First, operationalize the antecedents (skills/efficacy, norm salience, trust, ownership frames) alongside outcome metrics. Second, test causal pathways with pre/post cohorts, matched comparisons, field trials, or natural experiments in real settings. Third, probe boundary conditions across sectors and SME contexts, and document trade-offs where circular choices shift burdens onto users. This article is conceptual and builds a narrative synthesis; future empirical work should stress identification and replication. Advancing the circular transition requires redesign of systems and products and a deliberate reconfiguration of the antecedents that shape choice. The circular brainprint offers a map for that task and a set of propositions that invite testing in policy, education, and organizational practice.

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# Declarations

***Competing interests*** The authors declare no competing interests.



# References

Alarcón, J., Palma, M., Navarrete, L., Hernández, G., & Llorens, A. (2019). Educating on circular economy and DIY materials: how to introduce these concepts in primary school students?. In EDULEARN19 Proceedings (pp. 10083-10088). IATED.

Asif, F., Salehi, N., & Lieder, M. (2023). Consumer acceptance of product-service systems in the circular economy: The role of value perception and convenience. Journal of Cleaner Production, 418, 137943.

Beaurain, C., Chembessi, C., & Rajaonson, J. (2023). Investigating the cultural dimension of circular economy: A pragmatist perspective. Journal of Cleaner Production, 417, 138012.

Bonnett, M. (2002). Education for sustainability as a frame of mind. Environmental education research, 8(1), 9-20.

Borrello, M., Caracciolo, F., Lombardi, A., Pascucci, S., & Cembalo, L. (2020). Consumers' perspective on circular economy strategy for reducing food waste. Sustainability, 12(23), 10115.

Bourdin, S., & Torre, A. (2024). Economic geography's contribution to understanding the circular economy. Journal of Economic Geography, lbae040.

Bugallo-Rodríguez, A., & Vega-Marcote, P. (2020). Circular economy, sustainability and teacher training in a higher education institution. International Journal of Sustainability in Higher Education, 21(7), 1351-1366.

Calle Müller, C., Pradhananga, P., & ElZomor, M. (2024). Pathways to decarbonization, circular construction, and sustainability in the built environment. International Journal of Sustainability in Higher Education.

Camacho-Otero, J., Boks, C., & Pettersen, I. N. (2018). Consumption in the circular economy: A literature review. Sustainability, 10(8), 2758.

Daae, J., Chamberlin, L., & Boks, C. (2018). Dimensions of behaviour change in the context of designing for a circular economy. The Design Journal, 21(4), 521-541.

Davidescu, A. A., Apostu, S. A., & Paul, A. (2020). Exploring citizens' actions in mitigating climate change and moving toward urban circular economy. a multilevel approach. Energies, 13(18), 4752.

de Morais, L. H. L., Pinto, D. C., & Cruz-Jesus, F. (2021). Circular economy engagement: Altruism, status, and cultural orientation as drivers for sustainable consumption. Sustainable Production and Consumption, 27, 523-533.

Décamps, A., Allal-Chérif, O., & Gombault, A. (2021). Fostering knowledge of the sustainable development goals in universities: The case of sulitest. Sustainability, 13(23), 13215.

Décamps, A., Barbat, G., Carteron, J. C., Hands, V., & Parkes, C. (2017). Sulitest: A collaborative initiative to support and assess sustainability literacy in higher education. The International Journal of Management Education, 15(2), 138-152.

Fabiana, S., Valerio, M., Anna, P., & Mario, T. (2024). Fashion and sustainability: Evidence from the consumption of second-hand clothes. Corporate Social Responsibility and Environmental Management.

Gallego-Schmid, A., Chen, H. M., Sharmina, M., & Mendoza, J. M. F. (2020). Links between circular economy and climate change mitigation in the built environment. Journal of Cleaner Production, 260, 121115.

Gómez-Prado, R., Alvarez-Risco, A., Sánchez-Palomino, J., de las Mercedes Anderson-Seminario, M., & Del-Aguila-Arcentales, S. (2022). Circular economy for waste reduction and carbon footprint. In Circular Economy: Impact on Carbon and Water Footprint (pp. 139-159). Singapore: Springer Singapore.

Gonella, J. D. S. L., Godinho Filho, M., Campos, L. M. D. S., & Ganga, G. M. D. (2024). People's awareness and behaviours of circular economy around the world: literature review and research agenda. Sustainability Accounting, Management and Policy Journal, 15(5), 1118-1154.

Gonella, J. D. S. L., Godinho Filho, M., Ganga, G. M. D., Latan, H., & Jabbour, C. J. C. (2024). A behavioral perspective on circular economy awareness: The moderating role of social influence and psychological barriers. Journal of Cleaner Production, 441, 141062.

Grafström, J., & Aasma, S. (2021). Breaking circular economy barriers. Journal of cleaner production, 292, 126002.

Hachaichi, M., & Bourdin, S. (2023). Wheels within wheels: mapping the genealogy of circular economy using machine learning. Circular Economy and Sustainability, 3(4), 2061-2081.

Hartley, K., Roosendaal, J., & Kirchherr, J. (2022). Barriers to the circular economy: The case of the Dutch technical and interior textiles industries. Journal of Industrial Ecology, 26(2), 477-490.

Heshmati, A. (2017). A review of the circular economy and its implementation. International Journal of Green Economics, 11(3-4), 251-288.

Hina, M., Chauhan, C., Kaur, P., Kraus, S., & Dhir, A. (2022). Drivers and barriers of circular economy business models: Where we are now, and where we are heading. Journal of Cleaner Production, 333, 130049.

Hobson, K., Holmes, H., Welch, D., Wheeler, K., & Wieser, H. (2021). Consumption Work in the circular economy: A research agenda. Journal of Cleaner Production.

Janssens, L., Kuppens, T., & Van Schoubroeck, S. (2021). Competences of the professional of the future in the circular economy: Evidence from the case of Limburg, Belgium. Journal of Cleaner Production, 281, 125365.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular economy: Evidence from the European Union (EU). Ecological economics, 150, 264-272.

Lane, R., Lindsay, J., Arunachalam, D., & Raven, R. (2024). Repair and maintenance in Australian households: What drives this critical consumption work in the circular economy? Consumption and Society.

Lizana, J., Manteigas, V., Chacartegui, R., Lage, J., Becerra, J. A., Blondeau, P., ... & Almeida, S. M. (2021). A methodology to empower citizens towards a low-carbon economy. The potential of schools and sustainability indicators. Journal of Environmental Management, 284, 112043.

Lopes de Sousa Jabbour, A. B., Jabbour, C. J. C., Godinho Filho, M., & Roubaud, D. (2018). Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. Annals of Operations Research, 270, 273-286.

MacArthur, E. (2013). Towards the circular economy. Elen MacArthur Foundation.

Macklin, & Kaufman (2023). How do we change what we can't describe? A comprehensive Framework of User Behaviours in a materials circular economy. Circular Economy and Sustainability.

Maitre-Ekern, E., & Dalhammar, C. (2019). Towards a hierarchy of consumption behaviour in the circular economy. Maastricht Journal of European and Comparative Law, 26(3), 394-420.

Maria, M., Maesaroh, I., & Ginting, G. (2022, November). Proposing a Strategic Framework to Accelerate Circular Economic Practices: Strengthening the Willingness to Participate of the Young Generations as Agents of Change. In Journal of International Conference Proceedings (Vol. 5, No. 4, pp. 206-223).

Melles, G., & Paixao-Barradas, S. (2019). Sustainable design literacy: Developing and piloting sulitest design module. In Research into Design for a Connected World: Proceedings of ICoRD 2019 Volume 1 (pp. 539-549). Springer Singapore.

Mendoza, J. M. F., Gallego-Schmid, A., & Azapagic, A. (2019). Building a business case for implementation of a circular economy in higher education institutions. Journal of Cleaner Production, 220, 553-567.

Muranko, Z., Andrews, D., Newton, E. J., Chaer, I., & Proudman, P. (2018). The pro-circular change model (P-CCM): proposing a framework facilitating behavioural change towards a circular economy. Resources, Conservation and Recycling, 135, 132-140.

Musova, Z., Musa, H., & Rech, F. (2025). Circular economy challenges: a bibliometric exploration of cognitive and behavioral barriers. Journal of Organizational Change Management.

Neramballi, A., Milios, L., Sakao, T., & Matschewsky, J. (2024). Toward a policy landscape to support the product-as-a-service design process for a circular economy. Journal of Industrial Ecology, 28(5), 1045-1059.

Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). Circular economy: measuring innovation in the product chain. Planbureau voor de Leefomgeving, (2544).

Rizos, V., Behrens, A., Van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., ... & Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. Sustainability, 8(11), 1212.

Rogers, P. (2021). Rented but MINE! Application of psychological ownership theory to access-based consumption and the circular economy. Circular Economy and Sustainability, 1(2), 719-744.

Saarinen, A., & Aarikka-Stenroos, L. (2023). Financing-related drivers and barriers for circular economy business: Developing a conceptual model from a field study. Circular Economy and Sustainability, 3(3), 1187-1211.

Sanchez, B., Ballinas-Gonzalez, R., Rodriguez-Paz, M. X., & Nolazco-Flores, J. A. (2020, April). Integration of circular economy principles for developing sustainable development competences in higher education: an analysis of bachelor construction management courses. In 2020 IEEE Global Engineering Education Conference (EDUCON) (pp. 988-996). IEEE.

Scalabrino, C., Navarrete Salvador, A., & Oliva Martínez, J. M. (2022). A theoretical framework to address education for sustainability for an earlier transition to a just, low carbon and circular economy. Environmental Education Research, 28(5), 735-766.

Singh, P., & Giacosa, E. (2019). Cognitive biases of consumers as barriers in transition towards circular economy. Management decision, 57(4), 921-936.

Sukiennik, M., Zybała, K., Fuksa, D., & Kęsek, M. (2021). The role of universities in sustainable development and circular economy strategies. Energies, 14(17), 5365.

Sysoiev, O. (2021). Professional training in circular economy: challenges for Ukraine. European Humanitarian Studies, (1), 126-133.

Sysoiev, O. (2022). Trends in sustainable circular education transformation: a case of Finland. Education: Modern Discourses, (5), 142-151.

Van Langen, S. K., Vassillo, C., Ghisellini, P., Restaino, D., Passaro, R., & Ulgiati, S. (2021). Promoting circular economy transition: A study about perceptions and awareness by different stakeholders groups. Journal of Cleaner Production, 316, 128166.

Venn, R., Perez, P., & Vandenbussche, V. (2022). Competencies of sustainability professionals: an empirical study on key competencies for sustainability. Sustainability, 14(9), 4916.

Vidal-Ayuso, F., Akhmedova, A., & Jaca, C. (2023). The circular economy and consumer behaviour: Literature review and research directions. Journal of Cleaner Production, 418, 137824.

Waddilove, B. J., & Charnley, F. J. (2015). Development of a whole system design tool for business model innovation towards a circular economy. Product Lifetimes And The Environment.

Werning, J. P., & Spinler, S. (2020). Transition to circular economy on firm level: Barrier identification and prioritization along the value chain. Journal of Cleaner Production, 245, 118609.

Williams, M., McDonough, M., & Edge, S. (2017). Interdisciplinary circular economy design education through local and regional partnerships. In PLATE: Product Lifetimes And The Environment (pp. 432-436). IOS Press.

Žalėnienė, I., & Pereira, P. (2021). Higher education for sustainability: A global perspective. Geography and Sustainability, 2(2), 99-106.

Zibell, et al (2021). Expanding the knowledge base around the role of consumers in the circular economy: Promoting circular behaviour in textiles and electronics. Ricardo for the European Environment Agency.

Zimmerman, J., Wiek, A., Lang, D. J., & Wehrmeyer, W. (2024). Consumers and the circular economy: A systematic review of drivers and barriers. Journal of Cleaner Production, 433, 138521.