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Circular economy implementation challenges for achieving SDG 12

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Abstract

Despite the relevance of Circular Economy (CE) and the Sustainable Development Goal 12 (SDG 12) and the growing body of literature on the CE and SDG 12, there remains a significant research gap in systematically linking theoretical barriers to CE implementation with practical, industry-specific examples that demonstrate how these barriers impede progress toward SDG 12 targets. In this context, this paper explores the multifaceted challenges impeding the transition to a CE and its potential to contribute to SDG 12. There is a perceived need to address the challenges associated with the implementation of SDG 12. To analyse these challenges, this study uses two methods of analysis. The first was a critical analysis of the literature describing the challenges in achieving SDG 12. The second method consisted of assessing three case studies of companies from different sectors. The evidence gathered led to the listing of specific measures that may be implemented to address current challenges, including greater stakeholders´ integration, policy innovation, and consumer engagement. By identifying key barriers and proposing strategic solutions, this paper provides valuable insights that may enhance the implementation of CE principles, ultimately facilitating progress for meeting SDG 12 and fostering a sustainable future. Therefore, the present research moves beyond general descriptions of CE barriers and offers a practical roadmap for policymakers and businesses. It highlights the specific challenges that must be addressed to achieve measurable progress in resource efficiency, waste reduction, and sustainable consumption patterns as outlined by the 2030 Agenda.

Keyword Sustainability; circular economy (CE), SDG 12, Society, United Nation's Sustainable Development Goals (SDGs), Linear model

1 SDG 12: the case for a circular economy

According to the United Nations [57], the global material footprint increased by 70% between 2000 and 2015. In 2019, each person generated 7.3 kg of electronic waste (e-waste), and fossil fuel subsidies still threaten the achievement of the Paris Agreement and the 2030 United Nations Agenda. These are some of the numbers that represent the ecological urgency that society must face. The need for environmentally sustainable

development comes in response to environmental and moral imperatives, bringing a marked change in the importance of awareness and participation, not only by governments and industry but also of the entire society in the face of this ecological urgency [11, 45].

In this context, the Circular Economy (CE) proposes a shift from the linear "take–make–dispose" model to a restorative and regenerative system that keeps products, components and materials at their highest utility and value for as long as possible—thereby reducing virgin resource use and waste generation and aiming to decouple economic development from finite resource consumption [33, 34, 41, 50]. Operationally, CE unfolds through two complementary cycles: a technical cycle prioritizing maintenance, reuse, repair, refurbishment and remanufacturing before recycling/recovery, and a biological cycle in which biodegradable materials safely return to the biosphere [8, 43, 48, 49]. As originally conceptualized by the Ellen MacArthur Foundation (2013b), the Circular Economy is a regenerative system that goes beyond recycling, emphasizing product redesign, value preservation, and the avoidance of waste and energy loss throughout the value chain.

Because circular options can shift burdens, life cycle assessment (LCA) is needed to compare strategies and verify benefits across impact categories and stages [47]. While implementation varies across countries and sectors, reflecting institutional, technological and cultural contexts, the unifying aim remains resource efficiency, value retention and waste prevention within planetary limits [31, 32, 40]. In this sense, CE integrates and scales long-standing practices, remanufacturing, repair, cleaner production, and eco-efficiency, among others, into a systemic approach aligned with sustainable consumption and production [27, 51]. By generating reliable life-cycle data and sustainability performance metrics, CE provides the informational foundation for decision-useful corporate disclosure, thereby directly supporting SDG 12 targets on efficient resource use, waste prevention, and sustainability transparency.

The 2030 Agenda for Sustainable Development proposed by the United Nations (UN) contains 17 Sustainable Development Goals (SDGs). SDG 12, on Responsible Consumption and Production, demands paradigm shifts in terms of consumption and production patterns. This goal is detailed through eleven targets regarding: sustainable patterns of consumption and production (12.1), resources use efficiency (12.2), food waste (12.3), chemicals waste management (12.4), waste management (12.5), sustainability reports publishing (12.6), sustainable public procurement promotion (12.7), sustainability education for all (12.8), support scientific and technological development of developing countries (12.a), development of sustainable tourism (12.b), and changes in subsidies related to fossil fuel (12.c) [58]. This transition becomes necessary considering the acknowledged recognition that the Earth's resources are limited and that systemic changes in value chains, production processes, business models and consumer behaviour will have to occur most emphatically [32, 45],Q. [63, 64]. The CE approach proposes a change from the typical "linear" model (extract, produce, and dispose of) to a model that incorporates sustainability aspects and translates them into a "circular" model that manages the material flow in a different manner, reducing amounts, and re-inserting into the value chain [16, 43]. Despite variations among countries [32], CE is a different manner of managing products and components, restoring and regenerating them to

extend as much as possible their use and value, largely reducing waste generation [15, 31, 33, 47]. For that reason, CE and SDG 12 have strong connections.

Against this background, this study aims to better understand this discussion by performing a literature review that analyses what is being demanded by SDG 12 and what specific applications the CE proposes in the case studies provided. To structure the debate, the paper offers a conceptual approach to provide an understanding of the challenges to the CE for realizing SDG 12. The trend of using measurement mechanisms to monitor and direct the evolution of CE implementation is presented, which is closely related to progress towards SDG 12. The study offers a clear scientific contribution by connecting the basic ideas of the CE to the concrete, globally recognized goals of Sustainable Development Goal 12, Sustainable Consumption and Production. Although both concepts are often discussed together, this research provides a detailed assessment of how certain challenges in implementing CE slow down progress on SDG 12 indicators. Its uniqueness comes from creating and using a combined analytical framework that groups these challenges, technological, economic, regulatory, and social, not as separate barriers but as related system failures. By taking this approach, the study moves beyond general descriptions of CE barriers and offers a practical roadmap for policymakers and businesses. It highlights the specific challenges that must be addressed to achieve measurable progress in resource efficiency, waste reduction, and sustainable consumption patterns as outlined by the 2030 Agenda.

Despite the growing body of literature on the CE and SDG 12, there remains a significant research gap in systematically linking theoretical barriers to CE implementation with practical, industry-specific examples that demonstrate how these barriers impede progress toward SDG 12 targets. Existing studies often address challenges in isolation—focusing on either conceptual frameworks [33, 43] or sector-specific issues [10] —without integrating a comparative analysis across diverse organizational scales and value chain positions. This paper addresses this gap by conducting a critical literature review to categorize key challenges (technological, economic, regulatory, and social) as interconnected system failures and by examining three contrasting case studies (Airbus, Unilever, and Cano Water) to illustrate real-world manifestations and responses. This approach not only highlights underexplored interdependencies among barriers but also proposes a practical roadmap for stakeholders, offering a novel contribution to bridging theory and practice for enhanced CE adoption and SDG 12 achievement.

2 Methodology

This study utilises a mixed-method approach, combining a critical literature review with a multiple-case study analysis, to explore the challenges in implementing the CE facilitating SDG 12. This dual method allows for a comprehensive understanding by integrating theoretical insights from existing literature with practical evidence from real-world examples.

2.1 Critical literature review

The critical analysis of the literature was conducted systematically to identify and synthesise key challenges associated with CE and SDG 12. Relevant academic databases, including Scopus, and Web of Science, were searched using combinations of keywords such as "circular economy," "SDG 12," "sustainable consumption and production"

"barrier", "challenge" and "responsible consumption and production". The search was limited to peer-reviewed articles published between 2015 (the year the SDGs were adopted) and 2023 to ensure relevance to current global sustainability agendas.

The inclusion criteria focused on sources that discussed barriers, enablers, or linkages between CE principles and SDG 12 targets. Papers that did not focus on at least one of these three aspects were excluded from the sample. The papers selected were critically analysed to categorize challenges into thematic groups (e.g., economic, technological, regulatory, social, and operational), drawing on frameworks from authors like Wang et al. (2022a, b) and Rweyendela [52]. This review not only highlights persistent gaps but also informs the selection and analysis of case studies by providing a benchmark for evaluating real-world applications.

2.2 Case studies analyses

In line with Yin [65], a multiple-case study design was adopted to enable analytical generalization rather than statistical representation. Three cases were purposefully selected to capture typological variation: Airbus (a large industrial producer in the aviation sector), Unilever (a multinational consumer goods company with complex global supply chains), and Cano Water (a small-to-medium enterprise (SME) in the beverage industry). This selection ensures diversity in organizational scale, sector, and value chain position, allowing for comparative insights into how CE challenges manifest differently.

Data for each case were collected from reliable secondary sources, including corporate sustainability reports (e.g., [4, 62]), peer-reviewed publications (e.g., [12, 14]), and official company websites. No primary data collection (e.g., interviews) was conducted, as the scope of the study was focused on publicly available information to ensure transparency and replicability. Each case was treated as a holistic unit of analysis and thematically examined in relation to SDG 12 targets [59], such as resource efficiency (Target 12.2), waste reduction (Target 12.5), and sustainable practices in companies (Target 12.6). Themes were coded deductively based on the literature review's challenge categories and inductively to identify context-specific responses. Cross-case synthesis was performed to highlight common barriers (e.g., stakeholder commitment) and unique drivers (e.g., innovation in supply chains), facilitating a rigorous evaluation of CE contributions to SDG 12. This methodology ensures robustness by triangulating literature insights with empirical evidence, addressing the paper's aim to provide actionable recommendations for overcoming implementation challenges.

3 Results and discussion

3.1 Critical literature review: the challenges to achieving SDG 12

Various problems make the progress for meeting SDG 12 difficult, even for the most advanced economies [36]. When the indicators of SDG 12 are considered [59], it is possible to identify outstanding aspects related to this goal: natural resources use,food loss and waste; waste management to minimize negative social and environmental impacts; waste generation reduction through reuse, recycling and reduction; use of sustainability practices by companies and their reports; sustainable public procurement practices; access of information for the public regarding sustainable development; support (scientifically and technologically) for developing countries to seek sustainable development; and sustainable tourism.

Most of the SDG 12 targets can be connected. Among them, the link between natural resource use and waste generation reduction through reuse, recycling, and reduction can be emphasized. Sector-specific models, such as those in cruise sustainability reporting, demonstrate how CE practices in waste production can support SDG 12 while addressing marine biodiversity (SDG14), highlighting regulatory and stakeholder barriers [13]. As pointed out by Chiappetta Jabbour et al. [10] and Wang et al. [63, 64], in addition to reducing waste, the practices of reuse, recycling, and reduction can play a relevant role in minimising natural resource extraction.

Despite the several benefits provided by the development of a system that can maximize the use of resources by applying cyclical flows to production chains [10], Stekelorum et al., 2021), there are several barriers to its implementation. Among these barriers, Wang et al. [63, 64] present barriers relevant for different stakeholder groups, i.e., employees, government, consumers, companies, and partners. These are: (a) economic and financial, related to costs and the lack of assets, (b) technological, regarding the lack of technologies and technical knowledge; (c) commitment, from insufficient leadership and resulting from the lack of training and monitoring; (d) policies and legislation, resulting from the lack of an appropriate system of taxes and the lack of funding to support business; (e) society, regarding concerns about the environment, the products' quality-performance-safety and the lack of consumer engagement; and f) operational, related to the lack of infrastructure to enable the reverse logistics and associate activities, the lack of a supply chain structure for a circular purpose, and the difficulties to establish operational decisions.

When the reality of sustainable manufacturing (SM) is considered, other barriers are identified. Some of these barriers are the lack of knowledge about sustainability, the difficulty in understanding the environmental benefits of SM, the difficulty in linking financial gains and SM, the high level of trade-off to change the production to SM, and the lack of pressure from social actors, among others [66]. The barriers to comprise sustainability in industrial companies can be more complex for small and medium enterprises (SMEs) realities. As a result, these companies are responsible for a significant portion of occupational accidents, injuries, and environmental pollution [42, 55]. As evidenced by Tanco et al. [55], this reality is more impactful in developing countries where SMEs deal with more challenging conditions. Conceptual models for material waste management in textile manufacturing, particularly in contexts like Bangladesh, emphasise CE strategies to achieve SDG 12 targets such as waste reduction and resource efficiency [30]. These models illustrate the potential for upstream interventions to mitigate environmental pollution from SMEs.

Still in the context of industries, Rweyendela [52] emphasises the relevance of environmental impact assessment (EIA) as a tool to address the targets of SDG 12 and the contributions that Industrial Ecology (IE) may offer for them. However, the same author argues that there are important challenges for countries that seek IE implementation too. Among these challenges, the lack of knowledge of IE, communication among actors, causing a lack of information access, and the lack of financial resources can be mentioned. These challenges can be even more critical in developing countries [11]. A data-driven analysis of CE practices across world regions further underscores these disparities, revealing opportunities for policy alignment in resource efficiency and waste

reduction to advance SDG 12 targets [56]. This highlights the need for tailored strategies in emerging economies to overcome infrastructure and funding gaps.

When the efforts towards remanufacturing are considered, specific barriers can also be itemised. Among them, the European Commission [17] highlights the cost and complexity of logistics activities, the costs related to quality aspects of products remanufactured, the investment costs that are not rapidly returned, the need for transparency that can create risks to information security, customer resistance, and legislation barriers. It is also emphasized that the problems related to the lack of adequate legislation and quality standards can be higher in developing countries, where SDG-related investment is reduced (Leal Filho et al., 2022).

Finally, a collaboration network should be established among society, government, and retailers regarding the need to reduce food loss and waste. This collaboration should seek consumer education, which is a key step to reaching the mentioned reduction [38]. In addition to creating greater awareness of food waste avoidance amongst consumers, it is important to change the mentality of many consumers regarding the patterns surrounding high-quality food since food does not need to seem perfect to be proper for consumption. Digital CE frameworks can further support SDG 12 by integrating urban sustainability elements, such as reducing emissions through informed consumption patterns (Kannikar [29]). Despite this key role of consumers, food waste happens throughout the whole supply chain. In this sense, every stakeholder should be committed to avoiding food loss and waste, sharing this responsibility [20, 38]. The short shelf life of fruits and vegetables [46], for example, requires appropriate information management to enable a better connection between supply and demand [38, 39]. The mentioned challenges are summarised in Table 1.

The presented challenges in Table 1 indicate that the path towards a CE is not easy for the industrial sector. However, this reality also presents opportunities for businesses and researchers. In line with Yin [65], a multiple-case study design was adopted to explore how organisations operationalise CE principles in relation to SDG 12. The three cases, *Airbus*, *Unilever* and *Cano Water*, were purposefully selected to capture different organisational scales, i.e., large industrial producer, multinational consumer-goods company and SME, and distinct positions within the value chain. This typological variation enables analytical rather than statistical representativeness, facilitating theoretical replication and sectoral comparison. Each case was treated as a holistic unit of analysis, and the evidence was drawn from corporate sustainability reports, peer-reviewed publications and other reliable secondary sources. The information was thematically examined in relation to SDG 12 targets to identify common and context-specific challenges and

Table 1 Important challenges related to SDG 12 targets

Challenges	
Policies and legislation[b,i]	Consumer education/ awareness[a,b,i]
Stakeholders' commitment[b,c]	Knowledge[b,e,f]
Information management[d,e,i]	Unclear environmental benefits[f]
Economic and financial[b,e,f,i]	Quality assurance[i]
Technological[b]	High trade-off[f]
Operational[b,i]	Developing countries[e,g]
Pressure from social actors[a,b,f]	Communication[e]
Greater challenge–SME[g,h]	

Sources [a]Lemaire and Limbourg [38], [b]Wang et al. [63, 64], [c]Göbel et al. [20], [d]Mena et al. [39], [e]Rweyendela [52], [f]Yip and To [66], [g]Tanco et al. [55], [h]Neri et al.[42], [i]European Commission [17]

responses. This selection provides a spectrum of organisational scales and contexts: *Airbus* (large industrial producer), *Unilever* (multinational consumer-goos company with complex supply chains), and *Cano Water* (SME promoting sustainable consumption). This diversity aligns with Yin's [65] recommendation for case study research that enables analytical generalisation across contrasting settings, helping to reveal common and context-specific challenges in pursuing SDG 12.

3.2 Case Studies Analyses

4 Case Study 1. Airbus

Airbus, a leading aircraft manufacturer, exemplifies efforts to integrate CE principles into a high-tech industrial sector, focusing on lifecycle management to address SDG 12 targets like waste reduction (Target 12.5) and resource efficiency (Target 12.2). The company has established dedicated facilities, such as the Airbus Lifecycle Services (ALS) Centre, for end-of-life aircraft management, enabling the recycling of up to 92% of an aircraft's weight through materials like aluminum, steel, and titanium, as well as reusing components as Used Serviceable Material (USM) [2, 4]. This aligns with CE's emphasis on regeneration and waste minimization [16, 33].

However, rigorous analysis reveals significant barriers that hinder full CE adoption. A key challenge is the dependency on external partners like Tarmac Aerosave for decommissioning, which introduces operational complexities in reverse logistics and cost-effectiveness [3]. This resonates with Wang et al. (2022a, b)'s identification of operational and economic barriers, including infrastructure limitations and high investment costs with slow returns. Moreover, recycling composite materials remains technologically infeasible, exacerbating environmental impacts [53]. Capacity constraints—e.g., the ALS Centre's limit of 125 aircraft—pose scalability issues amid rising aircraft retirements, potentially undermining SDG 12 progress (Target 12.4 on waste management). Regulatory fragmentation across jurisdictions further complicates compliance, as varying environmental standards create inconsistencies (European [17]). Critically, Airbus's success depends on customer (operator) commitment, which may vary based on corporate policies, highlighting social and commitment barriers [66]. While Airbus promotes these services, the analysis indicates that without harmonized regulations and technological breakthroughs, CE efforts risk being symbolic rather than transformative, limiting contributions to SDG 12.

5 Case Study 2. Unilever

Unilever, a multinational consumer goods company, demonstrates CE application through its Sustainable Living Plan (launched in 2010), targeting SDG 12 aspects like sustainable sourcing (Target 12.4) and resource efficiency (Target 12.2) [37]. A prime example is its palm oil strategy, where Unilever co-founded the Roundtable on Sustainable Palm Oil (RSPO) and aims for deforestation-free supply chains by mapping and supporting smallholder farmers [61, 62]. This approach addresses CE's closed-loop ideals by enhancing transparency and investing in sustainable agriculture, given palm oil's high yield potential if managed responsibly [6, 7].

Analytical scrutiny, however, uncovers persistent challenges that mirror literature-identified barriers. Demand exceeding internal sustainable supply has forced reliance on

40,000 external smallholders, with only half mapped, risking inadvertent unsustainable sourcing [61]. This highlights economic and operational barriers, such as certification costs and training access for smallholders in developing countries [44, 52]. Linked to Debrah et al. [11]'s emphasis on knowledge and financial gaps in developing contexts, these issues could perpetuate deforestation, countering SDG 12 goals. Stakeholder commitment varies, with smallholders facing infrastructure deficits, aligning with Wang et al. (2022a, b)'s multi-stakeholder barriers. Quality assurance remains problematic, as unmapped suppliers may not meet standards, potentially leading to environmental backlash [54]. Comparatively, Unilever's scale enables advocacy (e.g., RSPO), but the analysis suggests that without accelerated mapping and tech integration (e.g., Industry 4.0 [1]), progress toward full CE integration and SDG 12 may stall, emphasising the need for stronger policy support in global supply chains.

6 Case Study 3. Cano Water

Cano Water, a UK-based SME in the beverage sector, embodies CE principles at a smaller scale, targeting SDG 12 through sustainable packaging and resource stewardship (Targets 12.5 and 12.2) (Cano [9]). By using infinitely recyclable aluminum cans instead of plastic bottles, the company reduces plastic waste and promotes material circularity [19, 60]. It also sources water sustainably and collaborates with stakeholders for resource recovery, fostering closed-loop systems (Ellen MacArthur Foundation, 2019).

A critical analysis, however, reveals vulnerabilities typical of SMEs, as noted by Tanco et al. [55] and Neri et al. [42]. Supply chain transparency is challenging, with difficulties in ensuring ethical sourcing and traceability, potentially amplifying environmental impacts [19]. This ties into operational and economic barriers, including limited resources for supplier audits (J. X. [63, 64]). Consumer behavior poses a major external hurdle: despite branding like "Don't bottle it" targeting eco-conscious personas, shifting habits toward recycling requires ongoing education, often insufficient against factors like price and convenience [18, 22]. Drawing on the Theory of Planned Behavior [21], intentions may not translate to actions without broader societal pressure. Comparatively, unlike larger firms like Unilever, Cano Water's scale limits influence over value chains, making it susceptible to market resistance and financial strains. The analysis indicates that while innovative, these efforts risk limited impact without partnerships and policy incentives, underscoring SMEs' greater challenges in meeting SDG 12 through CE (Table 2).

The outlined case studies have highlighted several features. While *Cano Water* has made commendable efforts to promote sustainable packaging and water stewardship, it may have problems related to scalability and consumer behaviour. Consumer behaviour reportedly impacts responsible consumption. The Reasoned Action Theory that Fishbein and Ajzen developed in the late 1970s focuses on the connection between marketing and pre-existing consumer attitudes, able to define purchasing decisions. When relating this to *Cano Water*'s CE efforts, it can be observed that consumers act on behaviours that they believe will create a specific outcome, such as sustainability, but this might not be the deciding factor [22]. Consumers' choices are often influenced by a variety of personal, social, economic, and psychological factors, as known [35]. In any case, the industry as a whole is still not producing and consuming beverages responsibly. In support, the Theory of Planned Behaviour, or the Self-Determination Theory, is commonly

Table 2 Summary of the SDG 12-related challenges in Airbus, Unilever, and Cano Water contexts

Case Study	Key Challenges Related to SDG 12	Barriers (Linked to Table 1 Categories)	Drivers/Strategies
Airbus	End-of-life aircraft management; recycling composites; capacity for rising retirements (Targets 12.4, 12.5)	Operational (reverse logistics complexity); Technological (composite recycling); Economic and financial (high costs, slow ROI); Policies and legislation (regulatory fragmentation); Developing countries (varying standards); Stakeholders' commitment (customer dependency)	Dedicated facilities (e.g., ALS Centre); Partnerships (e.g., Tarmac Aerosave); Promotion of recycling services; Advocacy for harmonized regulations
Unilever	Sustainable palm oil sourcing; mapping smallholders; supply chain capacity (Targets 12.2, 12.4)	Economic and financial (certification costs); Knowledge (smallholder training gaps); Stakeholders' commitment (external supplier engagement); Quality assurance (unsustainable risks); Developing countries (infrastructure deficits); Information management (mapping delays)	RSPO founding role; Investment in smallholder programs; Transparency initiatives; Adoption of Industry 4.0 for monitoring
Cano Water	Sustainable packaging; supply chain transparency; consumer behavior shift (Targets 12.2, 12.5)	Society (consumer resistance); Economic and financial (SME resource limits); Operational (traceability issues); Consumer education/awareness (behavior change); Greater challenge – SME (scalability); Pressure from social actors (market preferences)	Aluminum cans for infinite recyclability; Water stewardship practices; Stakeholder collaborations; Branding and marketing for awareness (e.g., "Don't bottle it")

used in observing people's recycling intentions. [21]. However, they are insufficient to influence after-purchase intentions, being crucial to understanding and examining the underlying motivational factors on individuals' reason to recycle. Further awareness of the impact of recycling could be considered to achieve SDG 12 and promote CE principles. By increasing its advocacy through marketing, *Cano Water* can inspire and support consumers in adopting responsible consumption practices, thereby helping to contribute to the broader goals of SDG 12 and advocating CE principles.

Similarly to *Cano Water*, *Airbus*'s recycling of aircraft is a pivotal factor in addressing SDG 12. However, instead of consumer behaviour, the industry behaviour and stakeholder engagement is seen as a long-standing challenge [5]. In order to address the challenges and promote sustainable aircraft recycling, *Airbus* must proactively promote the benefits of its recycling services and end-of-lifecycle channels to its stakeholders. In spite of this, there are still challenges that are industry-wide and hinder CE efforts, such as the need to create a clear business offering to stakeholder value chains and develop information security and confidentiality standards [28]. Such challenges are somewhat out of *Airbus*'s immediate control, yet they can play a role in advocating for harmonised regulations and guidelines for sustainable aircraft recycling. Although difficult to accomplish when considering competitors such as Boeing and operating within different global jurisdictions, engaging with relevant stakeholders, including regulatory bodies and industry associations, can contribute to developing standardised practices and regulations that support a CE approach. This collaborative effort will facilitate a smooth transition and ensure a sustainable future for the aviation industry. Even if *Airbus* achieves such collaborative efforts together with Boeing, there is still the significant challenge of the physical capacity to recycle. As a result, it is possible to assist the rhetoric of aiming to recycle aircraft falling short with the reality of current capacities and industry challenges.

Finally, with *Unilever*, it is possible again to observe external factors influencing a company's efforts to achieve SDG 12 and promote CE, as illustrated by the requirement

of *Unilever* to use up to 40,000 smallholder palm oil farmers. *Unilever* faces significant defiance in achieving sustainable palm oil sourcing. *Unilever* must work with suppliers to increase their capacity for sustainable production in order to eliminate the purchase of unsustainably produced palm oil, such as by utilising industry 4.0 technologies [1]. Smallholders account for a significant share of palm oil production, but, as mentioned before, they often lack the resources, knowledge, and infrastructure to adopt sustainable practices. *Unilever* must invest in training programs, provide technical assistance, and facilitate access to financing and certification processes to support smallholders in transitioning to sustainable palm oil production. Challenges related to supply chain capacity, smallholder farmer engagement, and the mapping process need to be addressed to achieve the desired level of sustainability. In particular, there may be cases where *Unilever* inadvertently purchases unsustainably produced palm oil. Similar to *Airbus*, the physical capacity and quality assurance challenges in ensuring responsible production and sourcing practices remain areas for improvement. Additionally, stakeholder commitment, particularly in developing countries where palm oil production is prevalent, may pose ongoing challenges in achieving sustainable palm oil sourcing. By actively addressing these challenges and continuously improving sustainability practices, *Unilever* can strengthen its position as a leader in sustainable palm oil sourcing and significantly contribute to advancing SDG 12. This example highlights the complexity of palm oil supply chains and the need for continued diligence and monitoring to ensure full compliance with sustainable sourcing practices.

The three outlined case studies have shown that *Airbus*, *Unilever*, and *Cano Water* all face challenges that can slow down progress in pursuing SDG 12, notably through factors that lie beyond the immediate control of the companies. This is a relevant reason for the relevance of properly managing supply chains. The addressed challenges in the three cases underscore the complexities and subtle nature of the issues involved in aspiring to achieve SDG 12 and the promotion of CE principles in practice. It also shows that, like in many other companies, responsible production is achievable, whereas the consumption area addressed by SDG 12 may be where significant challenges lie. Together, these case studies highlight that, while CE offers a systemic pathway to decouple growth from resource depletion, its sustainability is limited, primarily due to limitations in technology, governance capacity, and behavioural change.

Another important aspect that can be verified from the case studies is the possibility that companies from different sectors can gather insights from each other, considering the necessary adaptations for it. Despite the differences among the companies, there are important transversal aspects to be considered, such as the need to consider the circularity possibilities since product (and package) design, to have an appropriate supply chain management, to apply principles of sustainable procurements, to ensure resource efficiency, to properly prepare employees, and to have metrics to assess the performance.

The insights provided emphasize that meeting SDG 12 through the implementation of CE requires a multi-level approach, combining regulatory harmonization and circular standards at the macro level, inclusive and transparent governance at the meso level, and behavioural and reporting innovations at the micro level. In this sense, ISO standards such as ISO 20400 (sustainable procurement) [24], ISO 59004 (circular economy) [26], ISO 14040 (life cycle assessment) [23], and ISO 37004 (governance of organizations) [25]

can provide an essential support for organizations in the pursuit of SDG 12, providing concrete requirements.

7 Conclusions

As this paper has shown, the CE as an economic model presents several positive impacts on the environment, such as waste reduction and more efficient use of resources. It is closely aligned with SDG 12, focusing on establishing sustainable standards of consumption and production. The present study has addressed an important gap in the literature, systematically linking theoretical barriers to CE implementation with practical, industry-specific examples that demonstrate how these barriers impede progress toward SDG 12 targets. This paper has presented the factors that can hinder companies' pathway to SDG 12. One of the primary challenges is the limited understanding of concepts related to CE among businesses, policymakers, and the general public. Many stakeholders may not fully understand the potential advantages of CE or may not understand how to transition from linear to circular models. Raising awareness and providing education and training on circularity principles in the context of industry and stakeholders is crucial. Also, implementing SDG 12 requires collaboration and coordination across value chains, involving multiple stakeholders such as manufacturers, suppliers, consumers, and waste management systems. However, value chains are often fragmented, making it challenging to establish effective circular systems. Aligning the interests and incentives of the various actors involved in this respect is essential to overcoming these challenges.

A further issue is related to inadequate infrastructure. Many regions of the world lack the necessary infrastructure to support circular practices. Investing in recycling facilities, efficient waste management systems, and advanced technologies is crucial to enable the circular flow of materials. Also, the implementation of SDG 12 often requires upfront investments in new technologies, equipment, and infrastructure. The financial barriers can be significant, especially for SMEs that may have limited resources. Access to financing options, incentives, and economic/legislative support mechanisms can help overcome this challenge and encourage wider adoption of circular practices.

The analysed case studies have shown that some companies are very active in this field, and are trying to handle the specific challenges they face in a way that their efforts towards a sustainable production succeed. Here, the role of policy and regulatory frameworks should not be underestimated. In some cases, existing regulations may hinder the transition to circular practices. Governments need to develop and implement policies that promote resource efficiency, encourage recycling and reuse, and provide incentives to enterprises for adopting circular business models. In this sense, governments should use subsidies and taxes to incentivize desirable actions and hinder undesirable practices of companies. In this scenario, it is important to focus on the global impacts of these measures, considering social, environmental, and economic impacts generated through these initiatives.

Based on the findings of this study, it is possible to establish some measures companies may implement to implement CE practices and move towards achieving SDG 12.

i. *Sustainable Design*. Incorporate eco-design principles to create products that are easier to repair, recycle, or reuse, thus minimizing waste and resource consumption.

ii. *Resource Efficiency*. Optimise production processes to reduce resource inputs and energy usage. This can include adopting cleaner technologies and enhancing efficiency in material utilisation.
iii. *Supply Chain Collaboration*. Partner with suppliers and other stakeholders to create closed-loop supply chains that facilitate the recovery and reuse of materials.
iv. *Employee Training and Engagement.* Educate and involve employees in CE practices, fostering a culture of sustainability within the organisation.
v. *Sustainable Procurement.* Source materials from sustainable and ethical suppliers, prioritizing those who implement circular practices themselves.
vi. *Performance Metrics*. Develop and track sustainability metrics to assess progress towards CE goals and align strategies with SDG 12 targets.

It is worth highlighting that all these practices can directly impact the targets 12.2 (Resources use efficiency), 12.4 (Chemicals waste management), and 12.5 (Waste management) of the SDG 12, that are directly related to companies actions. Implementing these measures can help companies not only comply with SDG 12 but also drive innovation, reduce costs, and enhance their brand reputation.

Overall, implementing SDG 12 also needs to shift consumer behaviour and demand towards more sustainable and circular product acquisition. However, one has to bear in mind that consumer preferences and purchasing decisions are often driven by factors such as price and convenience rather than sustainability. Raising awareness, promoting sustainable lifestyles, and providing knowledge for consumers to choose circular products can help drive the demand for circular products and services.

While the cases examined are limited in number, the findings offer analytical generalisation to other sectors. The barriers identified, such as limited stakeholder engagement, infrastructure constraints, and regulatory fragmentation, are structural in nature and therefore relevant across industries aiming to advance SDG 12. Lessons from the three cases (*Airbus*, *Unilever* and *Cano Water*) can inform both manufacturing and service organisations that seek to integrate CE principles within their operations and supply chains. Addressing these challenges requires a holistic approach involving all stakeholders, including governments, businesses, consumers, and civil society organizations. Collaboration, innovation, and the adoption of supportive policies and measures are crucial to accelerate efforts towards SDG 12. Also, the complexity and scale are dimensions that companies may struggle to understand and have an influence on contribution to progress with regards to proposed responsible production solutions.

This paper has some limitations. The first is the fact that the analysis of the literature was limited to aspects of CE and SDG 12, and did not take other aspects, e.g. corporate social responsibility, into account. Also, the case studies were limited to 3 companies, which may not be representative of the whole spectrum of enterprises. In addition, it is important to highlight that the analyses presented are based on secondary data. Despite these limitations, the paper provides a welcome addition to the literature, since it provides insights on the difficulties associated with the implementation of CE and SDG 12, and some of the concrete actions being taken in that direction. Further studies examining SDG 12 should focus on how companies, industry, stakeholders and governments can positively influence responsible consumer behaviour and stakeholder engagement. Studies may also investigate how to foster SDG 12 by harmonising standards, promoting

international cooperation, and addressing trade barriers which can facilitate the global transition to a CE.

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Declarations

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Conflict of interest
The authors declare there is no conflict of interest.

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