Ünal, Enes; Sinha, Vikash Kumar

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Published in:
Business Strategy and the Environment

DOI:
10.1002/bse.3386

Published: 01/11/2023

Document Version
Publisher's PDF, also known as Version of record

Received: 8 April 2022 | Revised: 29 January 2023 | Accepted: 5 February 2023

DOI: 10.1002/bse.3386

RESEARCH ARTICLE

Business Strategy and the Environment

WILEY

Sustainability trade-offs in the circular economy: A maturity-based framework

Enes Ünal[1] | Vikash Kumar Sinha[2]

[1]Centre for Design Engineering, Cranfield University, Cranfield, UK

[2]Department of Accounting, Aalto University School of Business, Espoo, Finland

Correspondence
Enes Ünal, Centre for Design Engineering, Cranfield University, College Road, Cranfield MK43 0AL, UK.
Email: e.unal@cranfield.ac.uk

Abstract

The theoretical and practical understanding of sustainability implementation has been changing in depth and scope. In particular, circular economy paradigms (e.g., Cradle to Cradle or "C2C" practices) have enabled firms to rethink their resource management behavior, resulting in distinct trade-off patterns among different sustainability dimensions. Furthermore, while many established firms remain reactive and market-oriented in their sustainability implementations, sustainability-rooted firms proactively integrate sustainability practices into their core business. The prior literature on sustainability trade-offs has unduly focused more on established firms that predominantly indulge in market-oriented decisions and trade-offs between profit and sustainability, lacking insights into the approaches adopted by sustainability-rooted firms and trade-offs among the different dimensions of sustainability. We performed a mixed-methods study to address this gap and illustrated the rationale and dynamics of trade-offs among five sustainability dimensions (i.e., material health, material reutilization, renewable energy, water stewardship, and social fairness). We primarily focused on firms in the United States and the European Union since they are the leading areas in terms of circular economy adoption. We explained the pattern of sustainability trade-offs and associated them with a three-stage maturity framework, namely, low-hanging fruits, exploratory, and resource and time intensive. We contributed to the theory by depicting the influence of resource allocation and sustainability maturity level on trade-offs among the five dimensions of sustainability. Practitioners can leverage our framework to better understand their sustainability transformation and make more informed decisions for attaining higher levels of sustainability with more impact.

KEYWORDS

C2C, circular economy, Cradle to Cradle, maturity, mixed methods, sustainability, trade-offs

Abbreviations: C2C, Cradle to Cradle; MH, Material Health; MR, Material Reutilization; RE, Renewable Energy; SF, Social Fairness; WS, Water Stewardship..

1 | INTRODUCTION

The mainstream understanding of sustainability implementation converges on the fact that it requires firms to simultaneously address three quasi-conflicting and interdependent dimensions: economic, social, and environmental (Elkington, 2006). Scholars have suggested two contrasting perspectives for understanding how firms address these three distinct dimensions in their sustainability implementations: the *strategically justified* perspective based on the resource-based view and the *trade-off* perspective based on neoclassical economic approaches. The strategically justified perspective proposes that sustainability implementations invoke favorable responses from firms' stakeholders (customers, employees, media, society, and regulators) (Dyllick & Hockerts, 2002; Freeman, 2015; Tang & Tang, 2012). Favorable responses from stakeholders ultimately lead to the accumulation of financial benefits through various mechanisms, such as enhanced firm reputation (Brammer & Pavelin, 2006; Nardella et al., 2020), strengthened market differentiation (Vogel, 2005), cost reduction through complementary assets (Christmann, 2000), commitment from employees (Carmeli et al., 2007), and attraction of the best human capital (Surroca et al., 2010).

In contrast to the strategically justified perspective, the trade-off perspective suggests that limited resources at firms' disposal prompt them to sacrifice environmental and/or social goals and prioritize economic performance (Angus-Leppan et al., 2010; Figge & Hahn, 2012; Hahn et al., 2010; Margolis & Walsh, 2003; Nunes et al., 2020; Pinkse & Kolk, 2010). Some scholars posit that sustainability implementations can lead to costly investments that may not necessarily result in better financial performance of the firm, reflected in negligible stock market or product market returns (Friedman, 1970; Margolis & Walsh, 2003; Orlitzky et al., 2003; Rowley & Berman, 2000). In fact, many studies demonstrate that costs associated with sustainability implementations can even inhibit firms from either not implementing sustainability at all or pretending to adopt it (Delmas & Burbano, 2011; Surroca et al., 2013; van Marrewijk, 2003).

Despite a growing amount of research on the trade-off perspective, discussions mainly revolve around the conflicts between the economic and environmental dimensions or between the economic and social dimensions (Longoni & Cagliano, 2015; Nunes et al., 2020). Explicating the conflicts between the economic and sustainability dimensions, the trade-off literature is principally focused on the sustainability approaches applied by established firms (Cheng, 2020; DiVito & Bohnsack, 2017; Hockerts & Wüstenhagen, 2010). Therefore, such studies on trade-offs have focused on how established firms direct their slack resources while predominantly focusing on market-oriented economic goals (Longoni et al., 2019; Longoni & Cagliano, 2015; Nunes et al., 2020; Shevchenko et al., 2016). However, with the increasing number of firms transitioning toward sustainability practices by deploying business concepts such as circular economy or eco-effectiveness (Dyllick & Hockerts, 2002; Murray et al., 2017), sustainability trade-offs should be investigated in a more nuanced manner, including how these trade-offs are made (O'Reilly et al., 2018; Young & Tilley, 2006).

Recent research has demonstrated that, unlike established firms, many sustainability-rooted firms do not view economic goals as central to firms' decision making (Longoni et al., 2019; Longoni & Cagliano, 2015). By sustainability-rooted firms, we mean firms that use their scarce resources and different types of innovation to integrate economic, environmental, and social aspects in their core business (Klewitz & Hansen, 2014; Schönwälder & Weber, 2022). In fact, sustainability-rooted firms indulge in the "innovative process of creating market disequilibria" (Hockerts & Wüstenhagen, 2010, p. 482). In doing so, such firms use different mixes of both market-oriented (profit) and nonmarket-oriented factors (long-term environmental and social concerns) to manage their scarce resources in order to bolster their social, environmental, and ecological standings (Akhtar et al., 2018; Cheng, 2020; Hockerts & Wüstenhagen, 2010; Longoni & Cagliano, 2018). Hence, we argue that the market-oriented view of a trade-off between economic and sustainability dimensions limits our insights into how trade-offs are made by sustainability-rooted firms (Akhtar et al., 2018; DiVito & Bohnsack, 2017; Hockerts & Wüstenhagen, 2010).

In fact, noting the scarcity of research on trade-offs in sustainability-rooted firms and their mix of both market-oriented and nonmarket-oriented considerations, scholars have called for more research to clarify the pattern and process of trade-offs between different sustainability dimensions (Epstein et al., 2015; Longoni & Cagliano, 2015; Matos et al., 2020; Nunes et al., 2020; Shevchenko et al., 2016). Emerging research on trade-offs between environmental and social dimensions in sustainability-rooted firms highlights the complex nature of such trade-offs since different dimensions of sustainability are not only interrelated with one another but are also interconnected with traditional operational priorities of efficiency and effectiveness (Longoni & Cagliano, 2015).

Furthermore, sustainability-rooted firms make many decisions over a much longer term to achieve their ambitious goals, given that resources are always scarce (Pinkse & Kolk, 2010). Since trade-offs among different dimensions of sustainability are complex decisions that span a more extended period of time, research on the operational approaches of sustainability-rooted firms underlines the phase-wise manner in which firms implement sustainability (Shevchenko et al., 2016). In line with the literature on the operational approaches of sustainability-rooted firms, the literature on the maturity of sustainability practices also highlights what they term collaboration-intensive (Akhtar et al., 2018; Goworek et al., 2018) stepwise approaches (Julkovski et al., 2022; Schönwälder & Weber, 2022) to sustainability implementations. While the literature on trade-offs in sustainability-rooted firms has focused on the complexity of sustainability trade-offs without clearly linking them to different stages of maturity, scholars concentrating on the maturity of sustainability literature have focused more on firms' innovation, collaboration, learning, and resources without connecting them to the type of trade-offs. Given that firms have scarce resources and trade-offs are inevitable, we specifically focus on a central research question: *How do sustainability-rooted firms make trade-offs among different dimensions of sustainability?*

The trade-offs made by firms during sustainability implementation are complex, and theoretical insights into such trade-offs remain underdeveloped. One of the main reasons for the theoretical ambiguity stems from the fact that sustainability is an elusive concept (Dyllick & Hockerts, 2002), and many firms operationalize the concept differently (Bansal, 2003). Furthermore, the approaches to sustainability implementations are relatively subjective, which limits our insights into the level of sustainability achievements, that is, how mature the sustainability practices of firms are (van Marrewijk, 2003; van Marrewijk & Werre, 2003). To alleviate the ambiguities highlighted above, which reduce the trustworthiness of the results, we adopt a mixed-methods research strategy and use a more homogenous data set in which firms subscribe to a standardized perspective on sustainability. The data set comprises firms (and their products) that abide by a uniform perspective of sustainability (principles that make it possible to reach sustainability goals) and uses a standardized way of measuring sustainability through *Cradle to Cradle (C2C) product certifications* (Murray et al., 2017).

Empirically, we first conducted a quantitative analysis of 391 C2C-certified (v 3.1) products to identify different types of trade-offs among five sustainability dimensions made by sustainability-rooted firms in different stages of sustainability (C2C) practices. Afterward, we conducted a field study to understand how such firms make sustainability trade-off decisions. Our field study is based on interviews with sustainability managers and CEOs of both unique (the first and only firm to achieve the highest level of overall C2C certification v 3.1) and typical sustainability-rooted firms implementing C2C practices (Eisenhardt, 1989).

Our research makes three contributions to the literature on trade-offs in sustainability implementation. First, by exploring the trade-offs in sustainability-rooted firms among different sustainability dimensions, this research goes beyond the current debates, which mainly focus on established firms and explore the trade-offs between different sustainability practices and economic concerns (Epstein et al., 2015; Longoni & Cagliano, 2015; Nunes et al., 2020). Using purposive sampling, based on which we select sustainability-rooted firms, we are able to identify different trade-off patterns between different dimensions of sustainability (i.e., material health [MH], material reutilization [MR], renewable energy [RE], water stewardship [WS], and social fairness [SF]) (Borland & Lindgreen, 2013; Passetti & Rinaldi, 2020; Shin et al., 2018). Second, contributing to the literature on the multidimensional nature of trade-offs in sustainability-rooted firms (DiVito & Bohnsack, 2017), we identify three typologies of trade-offs (i.e., low-hanging fruit trade-offs, exploratory trade-offs, and resource- and time-intensive trade-offs) that such firms make between different dimensions of sustainability. Third, we extend the literature on sustainability implementation (Akhtar et al., 2018; Goworek et al., 2018; Julkovski et al., 2022; O'Reilly et al., 2018; Schönwälder & Weber, 2022) by demonstrating a relationship between different types of trade-offs and the maturity of sustainability practices in sustainability-rooted firms. In doing so, we argue that there exists a specific sequence of different trade-offs concerning different stages of sustainability implementation (i.e., maturity) and impact.

The rest of this manuscript is organized as follows. The next section presents an overview of the literature on sustainability trade-offs. Afterward, the methodology is discussed. The succeeding section offers insights into trade-offs between different sustainability dimensions. Then, we present the findings of our case study. Finally, the manuscript ends with a discussion of our main contributions by presenting our typology.

2 | TRADE-OFFS IN SUSTAINABILITY IMPLEMENTATIONS

The trade-offs in sustainability implementations have been explained from various perspectives. In doing so, scholars have gone beyond the apparent trade-offs among economic, social, and environmental goals and have explored the spatial, temporal, and contextual aspects of trade-offs (Haffar & Searcy, 2017). Scholars have suggested that firms make trade-offs among different dimensions of sustainability based on three important criteria: impact (Beckmann et al., 2014; Epstein et al., 2015), time (Bansal & DesJardine, 2014; Kim et al., 2019; Longoni & Cagliano, 2015), and process/resources (Akhtar et al., 2018; Hahn et al., 2010, 2015; Walley & Whitehead, 1994). Studies on impact-based trade-offs have focused on the trade-off among economic, environmental, and social goals/impacts (Dyllick & Hockerts, 2002; Hahn et al., 2010). Longoni and Cagliano (2015) suggested that newer innovations allow firms to manage trade-offs such that they can create a better overall impact. Studies focusing on time-based trade-offs have elaborated on how firms balance economic, environmental, and social concerns in their short-term and long-term strategies, planning, budgeting, and implementation approaches (Kim et al., 2019; Longoni & Cagliano, 2015; Shevchenko et al., 2016). Studies focusing on process/resource-based perspectives have highlighted trade-offs in the different strategic and implementation approaches that firms adopt in their sustainability implementations (Longoni et al., 2019; Longoni & Cagliano, 2015). Several scholars focusing on the process/resource-based perspective have also acknowledged the support of suppliers and business partners (Piazza et al., 2019) in complementing firms' internal resources and processes (Akhtar et al., 2018; Goworek et al., 2018; O'Reilly et al., 2018).

Emerging field studies are affirming the findings on trade-off decisions based on multiple dimensions (Kim et al., 2019) and complex prioritization logic (DiVito & Bohnsack, 2017). For example, Slawinski and Bansal (2012) and Longoni and Cagliano (2018) demonstrated that when firms define their time-based sustainability trade-offs for different planning horizons, they also include process and environmental uncertainty as well as their ability to learn as an important factor in such decisions. Kim et al. (2019) suggested that firms not only define short-term and long-term time horizons differently when making sustainability-related trade-offs but also incorporate process dimensions in their decisions. In short, emerging studies focusing on time-based trade-offs have demonstrated that firms make different types of trade-offs and that such trade-off decisions are based on multiple dimensions.

In addition to the multidimensional criteria for trade-offs, several emerging studies (cf. Haffar & Searcy, 2017; Hahn et al., 2010) have elaborated on not only the different dimensions (outcome, time, and process) but also the complex prioritization logic of trade-offs. In an extensive literature review, Haffar and Searcy (2017) suggested that different prioritization logics for trade-offs are made at different levels in firms. At the strategic level, firms utilize a comparative logic of trade-offs, relying on benchmarking factors such as the impact on various dimensions of sustainability, long-term versus short-term concerns, and which stakeholders to include or exclude. At the implementation level, firms make trade-offs by balancing the scope and scale of sustainability implementation (Goworek et al., 2018; Klassen & Vereecke, 2012; O'Reilly et al., 2018) as well as management (centralized vs. decentralized) (Hess, 2007, 2008) and measurement approaches (absolute vs. relative measurements). Further elaborating on the implementation-level challenges of sustainability that require technological change, Pinkse and Kolk (2010) and Kandemir and Acur (2021) demonstrated how firms apply a complex prioritization logic that includes their calculations on the compatibility between existing and new technologies and commercialization potential.

DiVito and Bohnsack (2017) demonstrated three prioritization logics of trade-offs: singular, flexible, and holistic. In singular trade-offs, firms focus on a dominant dimension of sustainability and relegate the other two dimensions to a secondary level. In flexible trade-offs, firms prioritize the three dimensions of sustainability in a certain order. In holistic trade-offs, firms use an integral view and try to enhance their impact on all dimensions of sustainability. The contested findings on dimensions and prioritization logic depicted in emerging field studies motivated us to inductively explore the ways firms make trade-off decisions. However, given that the scope and depth of sustainability implementations are changing with the transition toward a circular economy (indicating the change in resource management paradigm at different levels) and the emergence of new/alternative practices, we focused on a more nuanced understanding of the process and dynamics of sustainability trade-offs in a specific category of films that the literature identifies as sustainability-rooted firms.

Sustainability-rooted firms are defined as firms that integrate economic, environmental, and social aspects to define "core business" (p. 70) and aim to make a change (e.g., market transformation) by leveraging different types of innovations (e.g., product, process, organizational, or business model) (Julkovski et al., 2022; Klewitz & Hansen, 2014). These qualities are intrinsic to the Cradle to Cradle (C2C) certification scheme as "The Cradle to Cradle design principles provide a positive agenda for continuous innovation around the economic, environmental, and social issues of human design and use of products and services. Specifically, the purpose of the product certification program is to improve the way we make, use, and reuse things recognizing two metabolisms, the biological metabolism and the technical metabolism, with a goal to leave a beneficial footprint for human society and the environment" (MBDC, 2016, p. 2). Therefore, both qualitative and quantitative sampling in this study focus only on C2C-certified companies that fit the theoretical definition of sustainability-rooted firms. The field study provides further evidence on the logic behind such labeling and explicates the nuances to inform our final framework.

Recent research on trade-offs between environmental and social dimensions in sustainability-rooted firms underlines the complex nature of such trade-offs since different dimensions of sustainability are not only interconnected with one another but are also interrelated with traditional operational priorities of efficiency and effectiveness (Longoni & Cagliano, 2015). Furthermore, sustainability-rooted firms have to make a number of trade-off decisions over a much longer term to achieve their ambitious goals since resources are always scarce (Pinkse & Kolk, 2010). Given that trade-offs among different dimensions of sustainability are complex decisions that span a longer period of time, research on operational approaches of sustainability-rooted firms highlights the phase-wise manner in which firms implement sustainability (Shevchenko et al., 2016). In line with the literature focusing on the operational approaches of sustainability-rooted firms, the literature on the maturity of sustainability practices also highlights what they term collaboration-intensive (Akhtar et al., 2018; Goworek et al., 2018) phase-wise approaches (Julkovski et al., 2022; Schönwälder & Weber, 2022) to sustainability implementations.

Consequently, our study also goes beyond the win–win (strategically justified) and win–lose (trade-off) perspectives, which pit sustainability dimensions, such as the social and environmental dimensions, against the economic dimension. Specifically, our study focuses on the trade-offs made by sustainability-rooted firms among different dimensions of sustainability. In doing so, we respond to calls by scholars to shed light on the trade-offs between different dimensions of sustainability (Epstein et al., 2015; Longoni & Cagliano, 2015; Matos et al., 2020; Nunes et al., 2020).

3 | FIVE DIMENSIONS OF SUSTAINABILITY

The literature on the operationalization of sustainability mostly revolves around the triple bottom line (TBL) framework (Elkington, 2006) that is utilized to evaluate organizations' performance on social, environmental, and economic dimensions. Some argue that the TBL remains reductionist and misses critical nuances considering the broader interest of firms in sustainability implementation (O'Reilly et al., 2018; Young & Tilley, 2006), especially with the transition toward a circular economy (McDonough & Braungart, 2010).

One of the foundations and schools of thought of the circular economy is Cradle to Cradle, which is widely accepted by the industry as a stringent sustainability evaluation framework. As such, the Cradle to Cradle concept suggests five dimensions to assess sustainability, namely, MH, MR, RE, WS, and SF.

MH is linked to the safety verification of the content of industrial outputs and products (against the established list of allowed and banned list of chemicals), ensuring that no harm is caused to humans and the living environment (Borland & Lindgreen, 2013). MR is about product circularity through regenerative and restorative processes and ensuring that the product is part of either the biological cycle

TABLE 1 C2C scores and practices.

Sustainability dimension	Staggered scale for C2C scores: for certification level n, all practice-sets at n-1, n-2, … unto 1 are included Adapted from C2C product certification standard version 3.1	
Material health (MH)	C2C score	C2C practice sets
• Removing banned chemicals- toxic materials that contain any carcinogenic, mutagenic, or reproductively toxic (CMR) chemicals (Borland & Lindgreen, 2013) • Optimization of the product material's chemical formula—using environmentally friendly and safe materials (Borland & Lindgreen, 2013) • Meeting emission standards (Murray et al., 2017; Whiteman et al., 2013)	1	• No banned list chemicals are present above thresholds • Materials identified & defined as a biological or technical nutrient • 100% "characterized" (i.e., all generic materials listed)
	2	• Strategy developed to optimize all remaining X-assessed chemicals • At least 75% assessed by weight (100% for BN products)
	3	• At least 95% assessed by weight (100% for BN products)
	4	• Assessed materials do not contain any carcinogenic, mutagenic, or reproductively toxic (CMR) chemicals • 100% assessed by weight • Formulation optimized (i.e., all X assessed chemicals replaced or phased out) • Meets Cradle to Cradle defined emission standards
	5	• All process chemicals assessed and no X-assessed chemicals present
Material reutilization (MR)	1	• Defined the appropriate cycle (i.e., technical or biological) for the product and develop a plan for product recovery and reutilization
• Defining the material cycle as either biological (returning to the biosphere to be composted) or technical (to be recycled perpetually in the techno-sphere) (Borland & Lindgreen, 2013) • Developing a plan for product recovery and reutilization (Murray et al., 2017) • Stepwise progress based on measuring and improving the percentage of product's recyclable or compostable/biodegrade and recycled content (Dyllick & Hockerts, 2002) • Eventually, the product is 100% recovered in the technical and/or biological cycle (Murray et al., 2017)	2	• Designed or manufactured for the technical or biological cycle and has a material (re)utilization score ≥35
	3	• Designed or manufactured for the technical or biological cycle and has a material (re)utilization score ≥50
	4	• Designed or manufactured for the technical or biological cycle and has a material (re)utilization score ≥65 • Well-defined nutrient management strategy (including scope, timeline, and budget) for developing the logistics and recovery systems for this
	5	• Designed or manufactured for the technical or biological cycle and has a material (re)utilization score of 100 • The product is actively being recovered and cycled in a technical or biological metabolism
Renewable energy (RE)	C2C score	C2C practice sets
• Quantifying the emission/energy use related to the manufacturing of the product (Whiteman et al., 2013) • Developing a strategy for transitioning to renewable energy (Shin et al., 2018) • Stepwise progress based on measuring and improving the percentage of renewable energy use for manufacturing of the product (Whiteman et al., 2013) • Eventually, the product is produced with 100% renewable energy (Shin et al., 2018)	1	• Purchased electricity and direct on-site emissions associated with the final manufacturing stage of the product are quantified
	2	• Renewable energy use and carbon management strategy is developed
	3	• For the final manufacturing stage of the product, 5% of purchased electricity is renewably sourced or offset with renewable energy projects, and 5% of direct on-site emissions are offset
	4	• For the final manufacturing stage of the product, 50% of purchased electricity is renewably sourced or offset with renewable energy projects, and 50% of direct on-site emissions are offset.

TABLE 1 (Continued)

Sustainability dimension	Staggered scale for C2C scores: for certification level n, all practice-sets at n-1, n-2, … unto 1 are included Adapted from C2C product certification standard version 3.1	
• Characterizing the embodied energy for developing a strategy and finally optimizing it	5	• For the final manufacturing stage of the product, >100% of purchased electricity is renewably sourced or offset with renewable energy projects, and >100% of direct on-site emissions are offset. • The embodied energy associated with the product from cradle to gate is characterized and quantified, and a strategy to optimize is developed • ≥5% of the embodied energy associated with the product from cradle to gate is covered by offsets or otherwise addressed (e.g., through projects with suppliers, product redesign, savings during the use phase, etc.)
Water stewardship (WS)	C2C score	C2C practice sets
• Develop a strategy by characterizing local and business-specific water-related issues (scarcity or the impact) (Whiteman et al., 2013) • Having a facility-wide water audit (Passetti & Rinaldi, 2020) • Characterizing the chemicals in product-related effluent and supply chain relevant water issues to develop a strategy (Passetti & Rinaldi, 2020) • Removing problematic chemicals in the effluent (Whiteman et al., 2013) • Eventually, the effluent reaches drinking water quality	1	• The manufacturer has not received a significant violation of their discharge permit within the last two years • Local- and business-specific water-related issues are characterized (e.g., the manufacturer will determine if water scarcity is an issue and/or if sensitive ecosystems are at risk due to direct operations) • A statement of water stewardship intentions describing what action is being taken for mitigating • Identified problems and concerns is registered
	2	• A facility-wide water audit is completed
	3	• Product-related process chemicals in the effluent are characterized and assessed (required for facilities with product relevant effluent) OR • Supply chain-relevant water issues for at least 20% of Tier 1 suppliers are characterized and a positive impact strategy is developed (required for facilities with no product relevant effluent)
	4	• Product-related process chemicals in the effluent are optimized (effluents identified as problematic are kept flowing in systems of nutrient recovery; effluents leaving the facility do not contain chemicals assessed as problematic) OR • Demonstrated progress against the strategy developed for the silver level requirements (required for facilities with no product relevant effluent)
	5	• All water leaving the manufacturing facility meets drinking water quality standards

(Continues)

TABLE 1 (Continued)

Sustainability dimension	Staggered scale for C2C scores: for certification level n, all practice-sets at n-1, n-2, … unto 1 are included Adapted from C2C product certification standard version 3.1	
Social fairness (SF)	C2C score	C2C practice sets
• Conducting a full social responsibility self-audit to create a positive impact strategy (Murray et al., 2017) • Addressing the identified issues by creating management procedures • Investigating supply chain-related social issues to create a mitigation strategy (Murray et al., 2017) • Actively conducting innovative social projects (Longoni & Cagliano, 2015) • Leveraging internationally recognized social programs' third-party audit and getting certified (Longoni & Cagliano, 2015)	1	• A self-audit is conducted to assess the protection of fundamental human rights • Management procedures aiming to address identified issues have been developed
	2	• A full social responsibility self-audit is complete and a positive impact strategy is developed (based on UN Global Compact Tool or BCorp)
	3	• Material specific and/or issue related audit or certification relevant to a minimum of 25% of the product material by weight is complete (FSC Certified, Fair Trade, etc.) OR • Supply chain-relevant social issues are thoroughly investigated and a positive impact strategy is developed OR • The firm is actively conducting an innovative social project that positively impacts employee's lives, the local community, the global community, or social aspects of the product's supply chain or recycling/reuse
	4	• Two of the Level-3 requirements are complete
	5	• All three Level-3 requirements are complete

(nutrients for nature) or the technical cycle (to be recovered perpetually) (Murray et al., 2017). RE is associated with clean air and climate protection by leveraging green energy sources to reduce harmful emissions. WS aims to protect limited water resources and maintain soil health (Whiteman et al., 2013). SF concerns complying with human rights by enabling an equitable society with fair business operations (Longoni & Cagliano, 2015). The detailed table involving the proxies for each dimension is provided in n 4 (Table 1).

4 | METHODOLOGY

4.1 | Research strategy

This research employs a mixed-methods approach for two main reasons. First, trade-offs between different dimensions of sustainability are complex. Thus, the use of both quantitative (isolating trade-offs to understand what kind of trade-offs firms make) and field-based approaches (studying trade-offs in their social and organizational context to explain how trade-offs take place) can provide a better understanding of the phenomena (Molina-Azorin et al., 2017). Second, since the theoretical insights into the trade-offs between different sustainability dimensions are theoretically and empirically underexplored (Epstein et al., 2015; Longoni & Cagliano, 2015; Matos et al., 2020; Nunes et al., 2020; Shevchenko et al., 2016), mixed-methods research can not only provide the required empirical evidence but also offer a more trustworthy theoretical understanding (Molina-Azorin, 2012; Molina-Azorin et al., 2017).

In terms of the specific sequence of different methods, this article uses a sequential approach where quantitative analysis is carried out first, followed by a qualitative analysis (Molina-Azorin, 2012). Quantitative analysis is carried out to illustrate the different trade-offs firms make among five different sustainability dimensions. Subsequently, qualitative data (interviews, audio-visual material, and public and private documents) are analyzed to understand how firms make trade-offs between different dimensions of sustainability.

4.2 | Sample selection

The data are manually collected on 391 products with C2C-level certification (v 3.1) to carry out the quantitative analysis. Given the rigorous and continuous nature of C2C certification, firms implementing C2C practices can be considered sustainability-rooted firms that are committed to the cause of sustainability. Furthermore, the progressive nature of C2C product certification allowed the identification of different trade-off patterns and the establishment of linkages between the identified trade-offs and the achievement level of the sustainability dimensions at firms. Version 3.1 of C2C certification was selected since it has the most significant number of C2C-certified products and thus offered a larger sample size and variability to identify different trade-offs compared with other versions of certifications having a significantly smaller number of products.

Regarding the field study, firms with unique and typical C2C certifications were selected. The field study started with the interviews of the CEO, cofounders, and sustainability officers at the *unique* product firm that was the first and only firm achieving the highest level of overall C2C certification (v 3.1) (Yin, 1994). The field study also included interviewees from firms with different levels of certification and informants from the C2C Product Innovation Institute (C2CPII). The field study focused on firms located in the United States and the European Union since these two geographical regions are leading in terms of C2C implementation in particular and the circular economy in general. This diverse mix of sustainability-rooted firms allowed us to observe a more reliable and trustworthy pattern of how such firms make trade-offs between different sustainability dimensions.

4.3 | Data collection

4.3.1 | Quantitative data collection

Data on products with C2C certification v 3.1 were manually compiled from the C2C Product Registry database. The products were rated on five dimensions: MH, MR, RE, WS, and SF. Furthermore, the ratings on each dimension were categorized into five achievement levels: (1) basic, (2) bronze, (3) silver, (4) gold, and (5) platinum. All rating categories were associated with the evaluation of different sustainability practices (for more details, refer to Table 1). All products were also given an overall certification score equal to the minimum of the scores on the abovementioned five dimensions of sustainability.

4.3.2 | Qualitative data collection

In total, 17 interviews were conducted with CEOs, sustainability managers, and operations managers. The key informants were approached based on publicly available data on the websites of firms and the C2CPII. The focus was to select informants who were involved not only in strategic decisions on sustainability but also in the operational implementation of C2C practices. Such informants (with more than 15 years of experience) could provide relevant information on sustainability trade-off decisions. The details of the interviewees are included in Table 2.

Semistructured interviews were used that allowed the participants to freely express their opinions while guiding them to keep the discussion focused on our research objectives. An interview protocol was developed for the interview. The protocol included a definition of key terminologies and broad questions for the semistructured interviews. All interviews were conducted online through Skype, and the language of all the interviews was English. All interviews were recorded. While both authors were involved in all stages of the research, all the interviews were conducted by the first author. Thus, the first author acted as an empirical expert who tried to understand

TABLE 2 Data sources.

Firm	Industry and geography	Key informant/background	Interviews and duration	Secondary data - archive
A "best practice"	Building industry in the USA	CEO and cofounder/chemical engineering Sustainability officer and cofounder/health care—author in sustainability Client/architect Collaborator and sustainability expert/architect—author and consultant	One interview ≤ 1,5 h Five interviews ≤ 5 h One interview ≤ 1,5 h One interview ≤ 1,5 h	• Firm website • 59 magazine articles • 117 blog posts on the firm website, • 35 video recordings of the firm's social media channels • A book on sustainable design co-authored by the sustainability officer (entitled "bark house style: Sustainable designs from nature")
B	Mattress industry in EUROPE—the Netherlands	CEO/MSc business economics	Two interviews ≤ 1,5 h	Website, sustainability report
C	Hygienic paper industry in EUROPE—the Netherlands	Manager/engineering—quality	One interview ≤ 1 h	Website, sustainability report
D	Carpet industry in the USA	Director of sustainability/industrial engineering	One interview ≥ 1 h	Website, sustainability report
E	Carpet industry in EUROPE—the Netherlands	Director of sustainability/chemical engineering	One interview ≥ 1 h	Website, sustainability report
F	Office furniture industry in the USA	Product stewardship Sr. manager/MBA	One interview ≥ 1 h	Website, sustainability report
G	Recycled tire industry in EUROPE—the Netherlands	CEO/MBA—entrepreneur	One interview ≥ 1 h	Website, sustainability report
Institution—C2C Product innovation institute (PII)	Certification body—NGO in the USA	Stakeholder engagement manager/M.A. socially responsible business and sustainability Cofounder/chemist and professor	One interview and three webinars (the first author participated) ≤4 h Interview and informal interactions ≥ 1 h	• Websites of C2C PII, C2C market Place, C2C Environmental Protection Encouragement Agency (EPEA), C2C ExpoLAB, & C2C Centre • 60 innovation stories (including innovation stories of firms B, C, D, E, F), 38 documents on C2C inspired case studies from the C2C Centre, 27 documents detailing standards and policies from C2C PII public resources (including C2C V3.1 product standards) • 45 video (social media channel), 98 videos from C2C Centre • Two books by founders of C2C PII titled "Cradle to Cradle: Remaking the way we make things" and "the upcycle: Beyond sustainability—designing for abundance."

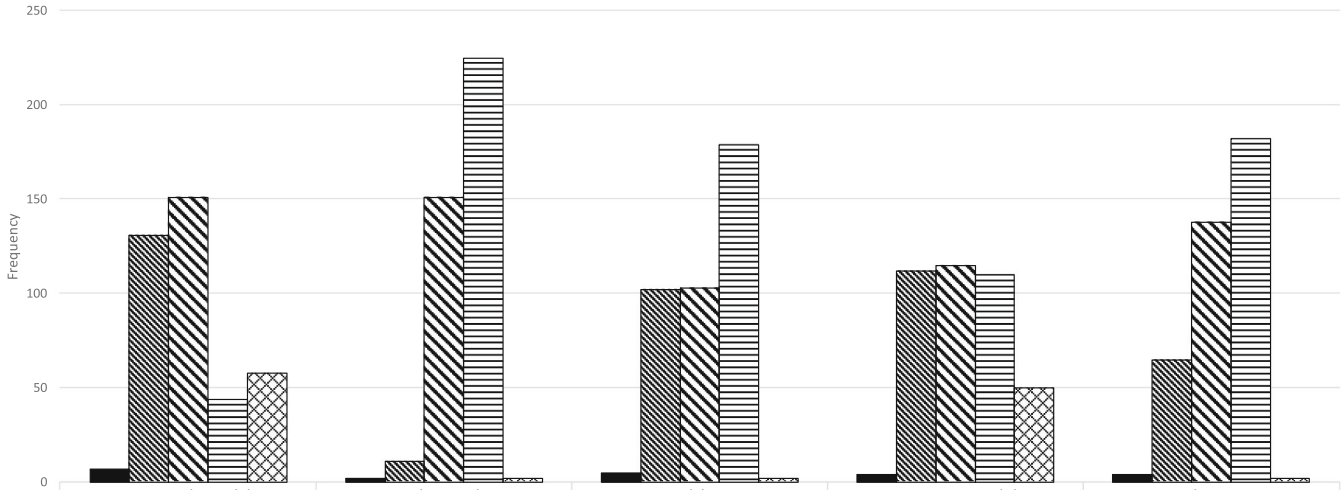
the viewpoint of the interviewees, and the second author acted as an objective outsider who was not influenced by his proximity to the interviewees. Participants were informed of anonymized reporting, allowing them to speak freely. Interviews lasted between 1 and 1.5 h. The interviews were focused on understanding several aspects: the product positioning of firms, the history of their sustainability practices (the logic, reasoning, and phases), the adoption of various sustainability certifications including C2C, trade-offs (prioritization of specific dimension[s] and resource allocation), the synergy (combined impact) in sustainability implementations, and factors influencing strategic and operational decisions on sustainability implementation. The participants were encouraged to share concrete examples during our interviews.

In addition to interviews, additional information was collected through publicly available sources: 3 books on the C2C concept and implementation, 27 documents on C2C standards and policies (including the handbook detailing C2C v 3.1), 60 innovation stories on firms implementing C2C practices, 38 documents on C2C-inspired case studies, 178 publicly available videos on the C2C approach and implementation, 3 webinars (the first author participated in the webinars), 59 magazine articles, and 117 blog posts from C2C-implementing firms. In addition to the abovementioned public sources, information from the C2C website as well as the websites and sustainability reports of firms included in the field study (A, B, C, D, E, F, and G) were also included in the analysis.

4.4 | Data analysis

4.4.1 | Quantitative data analysis

First, the median scores on all five dimensions of C2C practices for all products in each of the five maturity levels (designated by the overall C2C certification) were calculated. The median and dispersion for all five dimensions are reported in Figure 1. Since C2C scores on individual sustainability dimensions are ordinal in nature, median values were used instead of mean values. The median scores allowed us to infer an overall pattern suggesting trade-offs among the five dimensions of sustainability. A higher median score signified the prioritization of one dimension of sustainability over the other dimensions. Second, trade-offs for all possible pairwise combinations of the five sustainability dimensions for each of the maturity levels (since we had five dimensions of sustainability, that is, MH, MR, RE, WS, and SF, we had ${}^{n}C_{2} = 10$ pairwise trade-offs for each of the maturity levels) were derived. To validate the pairwise trade-offs between different dimensions of sustainability, the *sign test* function was used. The sign test function allowed us to test the median differences between matched pairs of sustainability dimensions in each of the five maturity levels (designated by overall C2C certification). Furthermore, using this function allowed us to verify whether the median differences between matched pairs of sustainability dimensions were zero, positive, or negative (in short, the method allowed us to ascertain which dimension of sustainability was prioritized).



	Material Health	Material Reutilization	Renewable Energy	Water Stewardship	Social Fairness
1	7	2	5	4	4
2	131	11	102	112	65
3	151	151	103	115	138
4	44	225	179	110	182
5	58	2	2	50	2
M	3	4	3	3	3

M=Median

FIGURE 1 Sample description. M = median.

4.4.2 | Qualitative data analysis and reliability

Five steps were followed to analyze the qualitative data. In the first step, all the interviews and publicly available data sources were categorized into appropriate categories by tagging them with firm names and the type of data (public vs. private). In the second step, historical and contextual narratives of all the case firms' sustainability implementations were developed. These narratives focused on identifying important events and decisions that potentially influenced the sustainability dimensions and their trade-offs. In developing the narratives, special attention was paid to historical events that suggested the adoption of sustainability and the major decisions made by the firms. To understand the contextual factors that can influence trade-off decisions, relevant information on product positioning (quality and price) and firms' commitment to sustainability were also identified. These contextual data points also established that the firms included in the field study were, in fact, sustainability-rooted. In the third step, all the relevant data points that depicted strategic and implementation-related trade-offs between different dimensions of sustainability were collated for all the case firms. To identify trade-offs, we focused on quotations where interview quotes suggested sacrificing one dimension over the other or prioritizing one dimension over other dimensions. In the fourth step, the stage, motivation, and impact of the trade-offs were identified. In the fifth step, the criteria for trade-offs were identified. To identify the criteria for trade-offs, iterating between empirical results and the extant literature facilitated identifying the three criteria (time, process/resources, and impact). Finally, by iterating between the empirical data and theoretical literature, the typologies of trade-offs were linked to the maturity and impact of sustainability implementations.

To maintain the reliability of the qualitative analysis, several approaches during data collection and data analysis were followed. First, to ensure the reliability of the data, the researchers created an interview protocol allowing for explaining key terminologies and goals of the project as well as asking a similar set of questions to the interviewees. Furthermore, the interviewers reiterated the key points of the conversation and confirmed them with the interviewees during the interviews or, in some cases, through email or during follow-up interviews. Second, to ascertain the validity of theoretical interpretation, the information shared by the participants during their interviews was triangulated with hard evidence through privately shared or publicly available documents. In addition, to further ascertain the validity of the theoretical interpretation, both authors read and reread the findings several times and discussed their differences in understanding multiple times. Moreover, the results were informally and formally presented to several experienced colleagues to ascertain the validity of the interpretation. Fourth, the traceability of data recordings and reliability of analyses was maintained by storing the cases and their analyses systematically (as a case database), making it possible to trace quotations to the original interviews.

4.5 | Sustainability trade-offs

Based on our quantitative analysis, including pairwise comparisons through the sign test function, we identified the following trade-off pattern of firms at different maturity levels of C2C practices (see Table 3 for more details).

Our quantitative analysis demonstrates that as firms advanced in their sustainability implementations, the trade-off between social (SF) and environmental (MH, MR, RE, and WS) dimensions diminished. This finding can be attributed to the way the C2C certification scheme works. Since the lowest score on any C2C dimension determines the overall certification level, firms are encouraged to progress in all five dimensions simultaneously. MH (i.e., toxicity issues) was one of the most challenging sustainability dimensions to implement for firms at early maturity levels of C2C certification. Firms at early maturity levels of C2C certification tend to focus on MR, and as they advance further, MH starts to become prominent. Accordingly, the trade-off patterns change and almost reverse as the maturity level advances.

The results from the quantitative analysis were corroborated through the field study. During interviews, several informants clearly stated that achieving a high score on the MH dimension was the most challenging. The requirement of MH for resource- and time-intensive research and development (R&D) and experimentation and coordination with suppliers to replace all toxic materials could explain why achieving a high score on this dimension was the most difficult. However, despite the challenges, remedying MH issues was seen in a relatively positive light by firms implementing C2C practices. The product stewardship manager at Firm F stated "What C2C has done is to raise the quality of the material that we use to make our products." In contrast to the challenges related to MH practices, MR through recycling and changing energy suppliers to renewable producers did not require experimentation or process changes. Consequently, achieving high scores on MR and RE was easier for many firms in the early maturity stages.

In many cases, trade-offs were also context dependent. For example, Firm A's historical focus on sustainable relationships with suppliers allowed them to adapt and quickly achieve high scores on the SF dimension. Furthermore, several informants also underlined that it was challenging for firms relying on energy-intensive processes to obtain high scores on this dimension since doing so required RE solutions that might not have been easy to address.

4.6 | Multidimensional tradeoffs

In this section, we first elaborate on the sustainability-rooted nature of our firms, followed by the three typologies of trade-offs.

4.6.1 | Sustainability-rooted firms

The firms with whose personnel we conducted interviews had focused on implementing and integrating sustainability programs in

TABLE 3 Trade-offs among different dimensions of sustainability.

Maturity level	Trade-offs among different dimensions of sustainability	Number of products	Verifying statistical significance of the pairwise patterns derived from overall trade-off (using *sign test* = test equality of matched pairs)									
			MH, MR	MH, RE	MH, WS	MH, SF	MR, RE	MR, WS	MR, SF	RE, WS	RE, SF	WS, SF
Basic (1)	MH < RE = WS < SF < MR	7	MH < MR**	MH < RE	MH < WS	MH < SF	RE < MR**	WS < MR	SF < MR	RE = WS**	RE < SF	WS < SF
			$p = .03$	$p = .25$	$p = .12$	$p = .12$	$p = .03$	$p = .10$	$p = .18$	$p = .00$	$p = .31$	$p = .50$
Bronze (2)	MH < RE < WS < SF < MR	168	MH < MR**	MH < RE**	MH < WS*	MH < SF**	RE < MR**	WS < MR**	SF < MR**	RE < WS	RE < SF**	WS < SF**
			$p = .00$	$p = .00$	$p = .09$	$p = .00$	$p = .00$	$p = .00$	$p = .00$	$p = .45$	$p = .00$	$p = .00$
Silver (3)	MH < SF < WS < MR < RE	150	MH < MR**	MH < RE**	MH < WS**	MH < SF**	MR < RE	WS < MR	SF < MR**	WS < RE	SF < RE**	SF < WS**
			$p = .00$	$p = .00$	$p = .00$	$p = .05$	$p = .40$	$p = .29$	$p = .00$	$p = .41$	$p = .00$	$p = .01$
Gold (4)	SF = MR = RE < WS < MH	65	MR < MH**	RE < MH**	WS < MH**	SF < MH**	MR = RE**	MR < WS**	SF = MR**	RE < WS**	RE = SF**	SF < WS**
			$p = .00$	$p = .00$	$p = .00$	$p = .00$	$p = .00$	$p = .00$	$p = .00$	$p = .00$	$p = .00$	$p = .00$
Platinum (5)	SF = MR = RE = WS = MH	1	The C2C certification scheme enforces this condition. Therefore, even with a sample size of more than one product, scores for all sustainability dimensions will undoubtedly be equal to 5.									

Note: To derive an overall trade-off pattern among five sustainability dimensions, we compared the median sustainability scores of the products on each of the five dimensions at different maturity levels. To validate the trade-off patterns among the five sustainability dimensions, we first identified 10 pairwise trade-off patterns for each maturity level (maximum pairwise combination, ${}^{5}C_{2} = 10$) by pairing two sustainability dimensions. After identifying the 10 trade-off patterns for all five maturity levels, we ran a pairwise sign test by grouping the pairwise trade-offs using the maturity level of certification.
**$p < .05$.*$p < .1$.*No star indicates* $p \geq .1$.

the operational processes of their high-quality products and were thus willing to invest in sustainability even when high investments were required. This willingness to integrate sustainability programs into operational processes indicates the sustainability-rooted nature of the firms we interviewed. The informants had divergent views on what signaled the high quality of their products, but these divergences were linked to the industries in which the firms were operating. For example, the cofounder of building materials Firm A suggested "pure aesthetic beauty" as a signal of high quality. The CEO of Firm B signaled his products' high-quality positioning by stating that their mattresses last longer, fetch a high resale value, are made with care, and are therefore high quality. A manager of a hygienic paper manufacturer (Firm C) argued that their products are for "special markets" where well-aware consumers are willing to pay for high-quality, sustainably produced hygienic papers even though the aesthetic quality of their products is low due to the use of recycled material. Explaining the high-quality positioning of their carpets, Firm E's director of sustainability signaled that "total quality sometimes (simply) means a higher price."

The sampled firms' sustainability-rooted approach was also reflected in their historical approaches focusing on recycling, green chemistry, and embeddedness in the environment and society. The manager of the hygienic paper manufacturer (Firm C) described their journey toward sustainability as a persistent focus on recycling that happened long before the firm considered C2C certifications.

> *Some 50 years ago, the company stopped using virgin paper as raw material and started using recycled paper. That's what we still do, at this moment. I think that that process started at our company 50 years ago, although people were not aware of it (…) Around 2007, our managing board with two directors, they were looking for a next step in the sustainability of our company, and that's how we came to know about the principles of Cradle to Cradle.*

Similarly, the director of sustainability at the carpet manufacturer (Firm D) explained their historical focus on green chemistry:

> *[Firm D] was involved in designing the product according to green chemistry principles even before the development of the term Cradle to Cradle. We were introducing a carpet product into an industry that had primarily offered PVC (polyvinyl chloride) carpet tiles [which are cheaper and difficult to recycle]. PVC chemistry was the dominant chemistry of that time, and [Firm D] intentionally designed a product that was not PVC.*

Some firms suggested that their founders and owners championed their high commitment to sustainability. The manager of hygienic paper manufacturing (Firm C) said "[Our founder is] very motivated, and he is (…) very keen on people, the planet, and profit." In a similar vein, the cofounder of building materials firm A stated the following:

> *When we started 20 years back, we weren't thinking about how much money we can line our pockets with. We were thinking about, you know, what kind of life do we want to live as members of a community and what contributions do we want to make.*

The owners of Firm G were so passionate about sustainability that they embarked on the arduous task of developing new technology themselves:

> *Initially, the core team looked for technology that was available in the market to recycle tires. They discovered the technology was not available, and as a next step, they started developing the technology itself.*

Several firms also suggested that their sustainability-rooted approach is deeply ingrained in their culture. The director of sustainability at carpet manufacturer, Firm D, explicated their commitment by highlighting how C2C resonates with their corporate culture:

> *It is very much aligned with our business vision and who we are as a company, doing the right thing, and it is a formality. It is formalizing a process for doing the right thing. It just very much aligns with our corporate culture of making sure that we design sustainable flooring products.*

The sustainability-rooted approach of firms was also reflected in their willingness to invest in management systems and innovations, resulting in additional certifications and improvements to practices beyond C2C certifications. The informant at the hygienic paper manufacturer, Firm C, stated the following:

> *We invest a lot in management systems, not only quality but also environmental safety and energy management systems (…) all our products are FSC (Forest Stewardship Council)-certified, all our products carry the European Ecolabel, some products carry the Nordic swan. We have won prizes from NGOs such as Best Managed Company for three years (…).*

In a similar vein, the senior manager of product stewardship at Firm F suggested that their long history of investment and innovation can offer lessons to firms willing to become sustainability rooted:

> *I think we have been at it for such a long time; we have added to that methodology, we used Cradle to Cradle, but we have used other methodologies that we have learned over the years to create more innovative products.*

In fact, the sustainability-rooted approach motivated firms to go beyond short-term perspectives and to invest in sustainability by prioritizing a long-term perspective. The CEO at Firm B explained as follows:

> *The return on investment will come. We are a family owned company, so we make decisions based on what we believe is right. It is part gut feeling and part business case, but it's a combination.*

The cofounder of Firm A echoed sentiment similar to that of the CEO of Firm B:

> *I mean, they're not always 100% smart business decisions. Sometimes, they're for the good of the community. They're not for the good of the business.*

The illustrated examples provide a pattern of the approaches of selected firms to sustainability. Accordingly, what makes firms in our sample sustainability-rooted is embedded within the history, culture, and reasoning behind their innovative and strategic activities that challenge the mainstream.

4.6.2 | Three typologies of trade-offs

Our analysis revealed three criteria for trade-off decisions (time, resources, and the outcome/impact on sustainability) and three typologies of trade-offs (*low-hanging fruit trade-offs*, *exploratory trade-offs*, *and resource- and time-intensive trade-offs*). In this section, we highlight the three typologies and their respective decision-making criteria.

Low-hanging fruit trade-offs

Such trade-offs required less change to processes and less time for implementation. They were also easily discernible during sustainability analysis and audits. Firms tend to indulge in such trade-offs, mainly in the early phases of sustainability implementation, by prioritizing material recycling/reutilization, RE, or energy savings. The CEO of the mattress manufacturer, Firm B, gave the example of local recycled aluminum sourcing, as it allowed them to reduce their CO_2 footprint.

> [During the early stages of C2C auditing and analysis], when we conducted source mapping, we looked at our aluminum sourcing from Vietnam, and we said, okay, the biggest CO_2 component in terms of transport needs are these legs, so we need to find solutions to source these legs from a different supplier close to our factory. The second aspect we also identified was that the legs are made with a high component of virgin aluminum. Therefore, we (…) looked at waste streams in the Netherlands for aluminum, and we found waste streams from several plants that had aluminum waste.

The local sourcing of recycled aluminum not only resulted in an improvement in the MR and MH (reduction in CO_2 emissions) practices in the whole supply chain but also allowed Firm B to improve its SF practices by engaging with local communities and firms that produce material with more transparent and better employee engagement practices. The CEO of Firm B stated the following:

> We are now using this aluminum waste as our starting point to create these legs in the Netherlands with a recyclability content of 98%, and that is very high for aluminum. (…) As a result, if you look at the specific bed models that are C2C certified, we have 1.5 million kilometers of logistical transport reduced to 30 thousand kilometers, which is a 75% reduction in CO_2 impact. In addition to improving emission standards [included in C2C MH ratings], we have improved our indicators on Material Reutilization as well as Social Fairness by engaging with local communities.

The cofounder of building materials Firm A gave the example of introducing kiln drying of bark, which they identified as a potential solution during their source mapping processes (conducted during the early stages of C2C auditing and analysis). Through the introduction of kiln drying, the proper insulation of kilns, and the usage of solar power, Firm A not only reduced its energy consumption (RE) but also enhanced the lifecycle of its products (MH).

> Well, the kiln drying was a big advance that we made in the processing of any of the bark materials. With the airtight construction, we rendered mosses and lichens on the bark materials inert. This enhanced the lifecycle of our bark material. (…) However, you know, kilns rely on heat, and it is an energy-consuming process to create heat. To improve energy usage, we maximized the kiln insulation and added systems to control the airflow and monitor the drying process stringently and rigorously. (…) And then, we added solar power to assist with renewable energy utilization. We reduced the energy usage and maximized our products' lifecycle through a clever improvement in the process in such a shorter period of time.

Exploratory trade-offs

Most of the time, such trade-offs were applied by firms when they were uncertain as to whether trade-offs would lead to any particular outcome concerning their sustainability dimensions without reducing their product quality. As a result, firms invested some time communicating with suppliers or contemplating changes in products or processes before they decided to move ahead with more significant investments of time and resources. Nevertheless, such trade-offs were significant for firms, as they enabled them to explore new materials or processes that could substantially impact their business and sustainability outcomes. Explaining such a trade-off scenario, the

CEO of the mattress manufacturer (Firm B) gave us the following example:

> We are looking at bioplastics at this moment, which are strongly emerging. (…) We're looking at the right alternatives to be applied in our production, in our products, where development might not be advanced enough yet for us to implement because of cost or quality.
> (…) For instance, consider that currently, we have material A in our product, and we have found an alternative material C, which is less hazardous than A. Nevertheless, if it would result in a lower-quality finished product, then we are not going to go for it. Therefore, we will need to research, and you can understand, with partners, how the solution with material C can be further improved through innovation or thinking so that eventually, when it does meet our acceptable quality standards, we can start using it.

The cofounder of building materials Firm A suggested that although they prefer engagement with the community and the reutilization of materials, whenever they contemplate newer types of engagements or materials that will require high investments, they tread cautiously so as not to sacrifice the high quality of their products.

> As far as product development goes, it is a big expense, and it is not always a guaranteed return. And again, a good example is many furniture makers that left our area. And at one point, we were contemplating, you know, do we take those furniture products and create other home offerings from them? We have been very slow to do that since we were not sure about the final products' aesthetic quality. We were gearing up to do that quite fast before the downturn. However, after the downturn, we have rethought that the thing that we are working on is valued engagement. And, as much as regeneration and regenerative processes rely on engagements with all of your stakeholders, we still struggle with it. We still struggle with letting people see the real value.

The cofounder of Firm A gave another example of their quest for creating biodegradable glue. The CEO described how biodegradable glue would allow them to do 100% biodegradable laminates:

> Not 100% of our products are fully biodegradable, and I would love the day (…) for example, we do some laminates, and the laminates call for glues, and to this day, there's not a true completely formaldehyde-free glue that holds very well. Therefore, most people will compromise, and they will deal with the not 100% green glue. And I wish that we could get to the point in the manufacturing of glues where there was an alternative of something out there I could use.

Using various platforms on which sustainability-oriented businesses communicated, Firm A found a supplier that was using almond-based glue for its plywood. He started encouraging the firm to test whether its products were biodegradable.

> Now, [a company] in [a nearby region] is already using a truly nice almond-based glue for their (.) plywood, and I would love for them to test that end product and see if it is 100% biodegradable. It could be. However, they haven't gone through the process of testing it.

The cofounder started negotiations with the supplier and focused on assessing their capacity to plan further joint research and development.

> And I talked with them over the years about "How much product can you make?" You know, "Can I use you, can I specify, you know, your backers," because, you know, they're biodegradable, and, "Could we look at ways to marry your product with my product?" I would love to see those things happening that each company tends to move it. You know, it pays.

While investigating biodegradable glue for new product lines, the cofounder was cautious since he understood that the experiment needed further thought and insights into whether such a product would have a demand in the market.

Resource- and time-intensive trade-offs

Such trade-offs required a massive amount of change in processes and coordination with suppliers, large investments, and longer time commitments. However, such trade-offs resulted in high impacts on the sustainability dimensions and improved the quality of products. The firms included in our field study invested in such practices because they were sustainability-rooted entities.

The CEO of Firm B explained their quest for oil-based paint. He stated that they identified the issue with oil-based paint when conducting their material mappings:

> With C2C, we started to look at the bed models that we made in 70 colors. With the ABC-X [as the MH assessment method], you start to focus on the X. One of the Xs we had in this prototype was oil-based paint. And we took the challenge as a company. We said we need to eliminate this because we want to have our own bed model C2C certified eventually. Therefore, how do we get rid of oil-based painting?

The CEO explained how they collaborated with a smaller firm in Germany to obtain oil-based paint technology to work for Firm B. The C2C certification, a high commitment to sustainability, and no compromise on quality were their major concerns in this quest.

The CEO also said that while they were not able to make an economic case for the old oil-based paint when they started, the water-based paint allowed them to cascade innovations and reduce waste, ultimately proving its "business case":

> What makes the business case eventually is that because we transitioned to water-based paint, we have been able to cascade innovations in our processes that were impossible with the oil-based paint. One of those innovations is the [shorter switchover time] when we're switching colors (…) from 20 minutes to under 1 minute. (…) [Moreover], the waste of water-based paint is no longer 32 cups, it is 1/2 a cup, so this is less waste. It is better for not only sustainable business practices but also my profit line. (…) This is an example of how C2C can help you to eventually improve on many dimensions of your operational excellence and your efficiency.

In an example of engagement with local small vendors (SF), the cofounder of building materials Firm A argued as to how their firm was able to procure source material with a smaller environmental footprint (MH).

> When you're looking at our supply chain, we're working with small logging crews, usually crews of two to three men. They're not your big logging crews that are out in the woods. So, they're working on an average of 10- to 20-acre tracts of property, and they're working with lighter equipment than these larger operations. So, they naturally have a smaller impact on the forest.

The cofounder of Firm A explained how they had trained their vendors for years to obtain high-quality source material as well:

> You know, we have 250 vendors who bring raw materials to us. (…) We train them all. One hundred percent of our suppliers are trained by us. So, we train them in the quality variables that we discussed. We train them in sustainability. We train them in best management practices. We share with them the know-how and practices that we want to see implemented. In a way, we not only give them specifications but also tell them how we want them to function in the forest sustainably. All this effort results in high-quality barks that are produced with less damage to the environment.

The cofounder stressed their commitment to engage with the local community despite concerns of economic viability with their sourcing approach in the following ways:

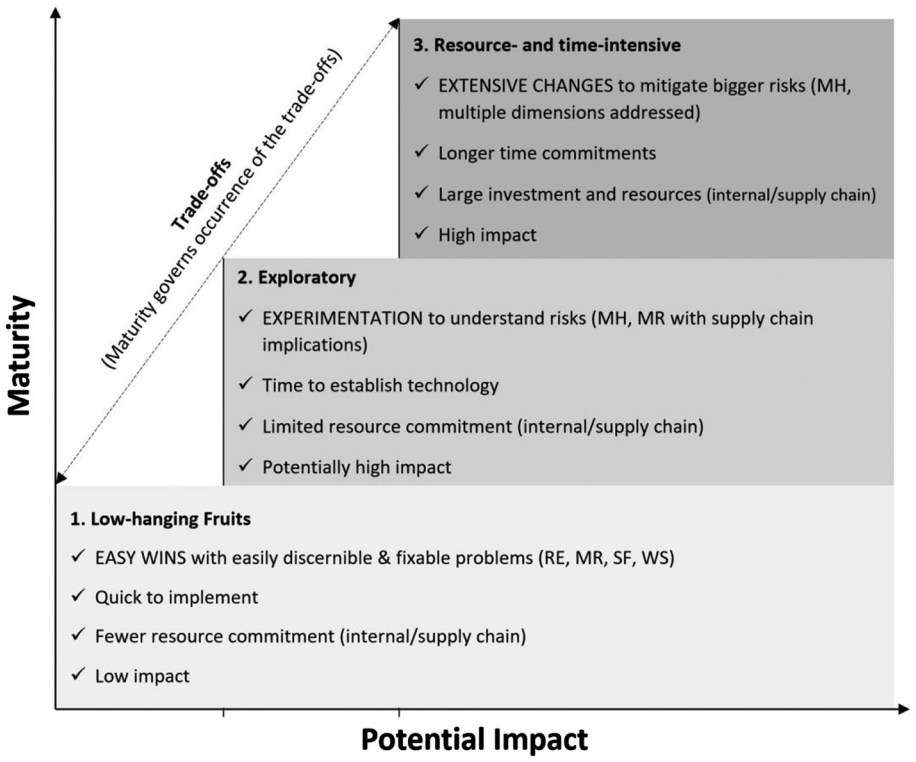


FIGURE 2 Sustainability trade-offs in the circular economy with respect to maturity. *MH, material health; MR, material reutilization; RE, renewable energy; WS, water stewardship; SF, social fairness. (Maturity indicates the level of advancements at the five sustainability dimensions).

> We train vendors who come to us for a year, and they save enough money to purchase a $50,000 piece of equipment, they never come back. However, at the same time, you know, we're bringing job opportunities, and there are years in which we will invest 70% of our income directly back into our community.

The CEO of Firm G gave examples of how their high commitment to sustainability allowed them to develop technology in collaboration with their customers, to seek investors and to roll out their products in the market.

> We started with the customers. So, basically, we went to all the big buyers of the carbon black, Michelin, Goodyear, PPG, (…) and basically tried to figure out what their specifications were that they should meet.

To achieve a product that performs, Firm G collaborated with its customers and scaled up its testing and processes over many years:

> Then, together with customers, we started our testing, and every time we had some samples, we shipped them to these customers to get feedback. (…) After the laboratory test, we made bigger machines and redesigned our processors so we could use off-the-shelf technology elements, as opposed to a sort of complicated self-designed machine. (…) Ultimately, we ended up with industrial trials and having many product validations by the R&D departments of all of these firms in place, which, as I described, is the first stage in commercial deals and technology that worked.

Once their technology was well tested and proven, they were able to obtain investments for commercial installations:

> Based on [years of hard work and the success in trials], we could finance (…) [we] got $10 million in financing for the first commercial installation, and now, we have the technology deployed at full scale.

5 | DISCUSSION AND CONCLUSION

Having identified three typologies of trade-offs, we build on the previous literature by extending the findings by Longoni and Cagliano (2015) and Nunes et al. (2020). In doing so, we contribute to understanding how sustainability-rooted firms make trade-offs between different dimensions of sustainability. We classify our contribution under three themes: clarifying the trade-off debate in the sustainability literature, introducing new typologies of trade-offs that highlight their multidimensional nature, and bringing a maturity perspective to trade-offs during sustainability implementation.

5.1 | Clarifying the trade-off debate in the sustainability literature

The mainstream approach to trade-offs in the literature tends to have a negative connotation associated with "tensions" (Nunes et al., 2020) or "paradoxes" (Matos et al., 2020). However, we demonstrate that trade-offs can be resolutions to challenges. Trade-offs help sustainability-rooted firms reach the ultimate goal of achieving higher levels of sustainability (in our case, a C2C score of 5) by facilitating continuous improvement in implemented practices. Furthermore, the economic, environmental, and social dimensions in sustainability-rooted firms are not perceived as competing (DiVito & Bohnsack, 2017; Longoni et al., 2019; Longoni & Cagliano, 2018). In contrast, these dimensions evolve in a self-reinforcing cycle. Accordingly, our result suggests that sustainability-rooted firms position sustainability as their *raison d'etre*, that is, the values and justification for their businesses' existence.

Unlike the dominant understanding of sustainability trade-offs where firms either fall under the business case frame (trade-offs are eliminated) or the paradoxical frame (trade-offs exist and are accepted) (Hahn et al., 2014, p. 467), we demonstrate that the trade-offs made by sustainability-rooted firms both fall under the business case and go beyond the business case (Dyllick & Hockerts, 2002), where firms invest in sustainability despite having difficulty measuring the outcomes (Hansen & Schaltegger, 2016). Using purposive sampling and selecting firms with a high commitment to sustainability (DiVito & Bohnsack, 2017), we were able to go beyond win–win (strategically justified) and win–lose (trade-off) perspectives (Epstein et al., 2015) and to identify different trade-off patterns among different dimensions of sustainability practices (MH, MR, RE, WS, and SF).

Our findings demonstrate that as sustainability-rooted firms advanced in their sustainability implementations, the trade-offs between the social and environmental dimensions diminished. This finding can be attributed to the way the C2C certification scheme intrinsically works. Since C2C encourages firms to make progress on different sustainability dimensions simultaneously by assigning the lowest score among the five C2C dimensions as the overall certification level, firms implementing C2C have to plan for high scores on all the dimensions (Murray et al., 2017). MH (i.e., material toxicity issues) was one of the most challenging sustainability dimensions to implement since it required a high level of coordination with the supply chain (innovation, skills, and resources) and resource- and time-intensive trade-offs that facilitated the search for replacement materials and process changes.

5.2 | Typology of trade-offs highlighting their multidimensional nature

We introduce an inductive typology that was informed by a mixed-methods analysis. Since the theoretical understandings of the trade-offs between different sustainability dimensions are underexplored and more empirical evidence is being sought by scholars (Epstein

et al., 2015; Longoni & Cagliano, 2015; Matos et al., 2020; Nunes et al., 2020; Shevchenko et al., 2016), we deployed a mixed-methods approach to obtain more trustworthy results. Our results indicate that sustainability-rooted firms not only exploit readily available technologies to achieve faster results (low-hanging fruit trade-offs) but also do not shy away from cautiously exploring innovation approaches (exploratory trade-offs) that require coordination with their suppliers and customers (Bansal, 2005; Beckmann et al., 2014; Kim et al., 2019; Longoni & Cagliano, 2015; Young & Tilley, 2006). In highlighting the three typologies of trade-offs, we extend the literature on how sustainability-rooted firms (unlike established firms) do not make simple trade-off decisions based on a single criterion of outcome/impact, time, process, or quality (Haffar & Searcy, 2017; Hahn et al., 2010). Instead, sustainability-rooted firms indulge in multidimensional trade-offs, where they weigh their decisions based on multiple criteria (Angus-Leppan et al., 2010; DiVito & Bohnsack, 2017; Young & Tilley, 2006).

5.2.1 | Low-hanging fruit trade-offs (quick to implement, fewer resources committed, quick impact on sustainability)

The trade-offs at the early phases of sustainability implementation (C2C scores 1 and 2) might stem from sustainability-rooted firms' previous experiences as well as easily discernible problems. Skills, capabilities, and coordination might not be readily available at the beginning phases of sustainability implementations to address all dimensions simultaneously (Goworek et al., 2018; O'Reilly et al., 2018). Furthermore, sustainability-rooted firms may be reluctant to make large changes without understanding the consequence of change on their product quality (Schönwälder & Weber, 2022). Such concerns may explain why sustainability-rooted firms in the early stages focused on using recycled metals (MR) or switching to RE that required no or minimal process changes. Furthermore, we contend that the trade-offs at the early stages might also be affected by the temporal nature of C2C certifications (2 years) (MBDC, 2016, p. 17). In addition, each renewal is expected to be an improvement on the previous version/state. Accordingly, firms seek a quick win to save time and resources for later phases, as certification might be a long journey (Angus-Leppan et al., 2010).

5.2.2 | Exploratory trade-offs (investment of time and resources for experimentation, a potentially high impact on sustainability)

To transition toward all five sustainability dimensions, many sustainability-rooted firms needed radical changes in their procurement, design, and production processes, including the techniques and technology used. In some cases, sustainability-rooted firms even needed to invent a new technology (related to production or material) from scratch. Before making radical changes, sustainability-rooted firms indulged in experimentation and exploratory trade-offs to understand their risks (Cheng, 2020; Longoni & Cagliano, 2015; Slawinski & Bansal, 2012). Experimentations required limited internal/external resource commitments and enabled understanding of value chain barriers (i.e., product formulations—a lack of willingness with regard to information sharing, replacing suppliers, and recovering materials) (Bortolotti et al., 2015). Pursuing such trade-offs, sustainability-rooted firms tended to initiate collaborations through their supply chain partners, as it was not possible to reach sustainability goals solely in-house (Julkovski et al., 2022; Pinkse & Kolk, 2010). In addition, we can view these trade-offs as careful steps by sustainability-rooted firms where they invest time and resources to first explore future possibilities before making more significant investments.

5.2.3 | Resource- and time-intensive trade-offs (longer duration, more resources committed, a high impact on sustainability)

Once sustainability-rooted firms understood their risks through exploratory trade-offs, they tended to indulge in resource and time-intensive trade-offs where they made changes to their processes and raw materials without compromising the quality of their products. Firms in our sample made such trade-offs because they were deeply committed to the cause of sustainability (DiVito & Bohnsack, 2017; Young & Tilley, 2006). Firms making such trade-offs not only committed internal resources and communicated their sustainability ambitions to their business partners (Zarei et al., 2019) but also sought support from their business partners to implement changes (Akhtar et al., 2018; Goworek et al., 2018; Julkovski et al., 2022; O'Reilly et al., 2018). The rationale of such trade-offs was grounded in the culture of sustainability-rooted firms and their internalization of sustainability goals.

5.3 | A maturity perspective on trade-offs: Future research opportunities

Finally, we extend the literature on sustainability maturity (Akhtar et al., 2018; Goworek et al., 2018; Julkovski et al., 2022; O'Reilly et al., 2018; Schönwälder & Weber, 2022) by demonstrating a relationship between different types of trade-offs and the maturity of sustainability practices in sustainability-rooted firms (as summarized in Figure 2 below). We invite scholars to further explore the linkages between the maturity of sustainability practices and sustainability-related trade-offs. One can argue that some sustainability dimensions are in very early stages in specific industries and are therefore difficult for firms to implement (i.e., fashion firms have difficulty verifying the social fairness of their supply chain partners in emerging countries) (Akhtar et al., 2018; Goworek et al., 2018; O'Reilly et al., 2018). In contrast, it is noteworthy that in dimensions of sustainability such as MH and MR, firms or industries (in our case, Firm A and industries

focusing on biomaterials) that position themselves as being part of the biological cycle (returning natural materials to the biosphere) have a built-in advantage over firms characterized by the technical cycle (Borland & Lindgreen, 2013). Therefore, we argue that maturity matters in terms of where sustainability-rooted firms start in their sustainability journey with respect to where they are going to finish (what is possible with resources, time, and capital) (Shevchenko et al., 2016).

We contend that trade-offs are essential for eventually reaching a no-tradeoff scenario (Beckmann et al., 2014; Dyllick & Hockerts, 2002). Furthermore, sustainability trade-offs may not be mutually exclusive, as sustainability-rooted firms might need to make several trade-offs simultaneously. Therefore, we suggest conducting a longitudinal case study of firms from different industries to better understand trade-offs and further extend our framework.

ACKNOWLEDGEMENTS

We thank participants at EUROMA 2020 and Academy of Management Annual Conference 2021 and 2022 for their valuable feedback.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this research.

ORCID

Enes Ünal https://orcid.org/0000-0002-0593-4182
Vikash Kumar Sinha https://orcid.org/0000-0002-7253-4779

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How to cite this article: Ünal, E., & Sinha, V. K. (2023). Sustainability trade-offs in the circular economy: A maturity-based framework. *Business Strategy and the Environment*, *32*(7), 4662–4682. https://doi.org/10.1002/bse.3386