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CATALYSING THE TEXTILE INDUSTRY TOWARD A CIRCULAR ECONOMY

An ecosystem approach

Olga Dziubaniuk, Leena Aarikka-Stenroos, and Eeva-Leena Pohls

Introduction

'Circular economy' (CE) is an umbrella term and paradigm referring to CE models and circular processes in industrial structures that enable a reduction in the use of natural resources and the generation of waste by adopting the principles of recycling, reuse, and reduction to increase circularity (Geissdoerfer et al., 2017; Murray et al., 2017). High environmental impact industries, such as construction, textiles, and food have begun to initiate changes toward more circular operations (e.g., Fischer & Pascucci, 2017; Franco, 2017; Hossain et al., 2020). However, these changes can be difficult to implement as a rapid shift to circularity-enabling technologies and adoption of CE business models can disturb conventional business and operation processes, including related value chains, and demand changes in collaboration and competition (Aarikka-Stenroos et al., 2021; Ritzén & Sandström, 2017). Changes in industries frequently concern their whole socio-technical systems, including the regulatory domain (Geels & Kemp, 2007). Therefore, it is important to consider the entire industrial system and its actors, which can be conceptualized as an ecosystem in which diverse complementary, yet interdependent industrial and social actors share values, pursue system-level outcomes, and develop through coevolution (e.g., Aarikka-Stenroos & Ritala, 2017). When this consideration is applied to CE framing, such ecosystems can be conceptualized as CE ecosystems (CEEs) that seek system-level circulation of resources and materials through recycling, reuse, and reduction and involve companies, governmental organisations, regional bodies, policymakers, and consumers (Aarikka-Stenroos et al., 2021). Such CEEs facilitate collectively created sustainable value (Aarikka-Stenroos et al., 2021; Uusikartano et al., 2020). CEEs can focus, for instance, on regional or industrial circular resource flows (circular urban and industrial ecosystems) or a company's evolving relationships to drive economic value creation (circular business ecosystems) (Aarikka-Stenroos et al., 2021). In this chapter, we are particularly interested in a system of diverse actors enabling textile circulation and in identifying what could drive the textile industry towards increased textile recycling and reuse as a system-level outcome.

Research has paid increasing attention to the textile industry's pursuit of environmental sustainability through circularity (Filho et al., 2019; Franco, 2017; Hole & Hole, 2019; Moretto et al.,

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2018; Niinimäki & Hassi, 2011). Naturally, the textile industry causes an environmental impact since it represents a massive share of the world's manufacturing industries, and the production volumes of textile fibres have been increasing continuously in recent years (Bick et al., 2018; Ellen MacArthur Foundation, 2017; Textile Exchange, 2021). Global textile production in 2020 reached 109 million tons, of which 91.9% was virgin fibre feedstock (e.g., polyester, acrylic, cotton), and only 8.1% was recycled fibres (Textile Exchange, 2021). Textile production and fashion are now among the most polluting industries that threaten environmental and social well-being (Bick et al., 2018; Boström & Micheletti, 2016; Koszewska, 2018; McFall-Johnsen, 2020). Therefore, the industry is in urgent need of large-scale systemic changes in both production and consumption patterns to take a leap towards sustainability and circularity (Boström & Micheletti, 2016; European Environment Agency, 2017).

As the systemic shift toward circularity is arduous, there is a growing number of studies addressing drivers and barriers that enable or inhibit companies, industries, and countries in the move toward CE (e.g., Jia et al., 2020; Kirchherr et al., 2018; Ranta et al., 2018; Tura et al., 2019). The drivers and barriers are, for instance, technologies (De Jesus & Mendonça, 2018), consumer behaviour and adoption of CE principles (e.g., Singh & Giacosa, 2018), institutional and organisational drivers (Aloini et al., 2020; Jia et al., 2020), and industrial infrastructure (e.g., Fischer & Pascucci, 2017). However, these studies have made little contribution to uncovering the comprehensive set of driving catalysts that is needed for versatile actors to facilitate the circulating system. Hence, the current study aims to address this research gap by exploring the diverse catalysts for circularity as perceived by the ecosystem actors. To do so, we apply the catalyst conceptualisation, which refers to the mechanisms that drive or inhibit the change (Cabell & Valsiner, 2011). The concept of a catalyst (Cabell, 2010; Valsiner, 2013) is applied in this study as a metaphor for diverse enablers and conditions for CE in an industrial ecosystem.

To uncover circularity catalysing mechanisms in textile CEEs, and due to the pragmatic relevance of textile circulation from sustainability and business perspectives, we pose three research questions: (1) What ecosystem is needed for increased textile circulation within the textile industry? (2) What are the key catalysts for textile circulation? and (3) how do key catalysts enable and create favourable conditions for the textile CEE development? Empirically, this research is framed as a qualitative case theory (Gummesson, 2017) grounded on extensive data collected from the ecosystem actors involved in textile circulation in Finland. The Finnish context provides a fruitful background for our study as, within the past decade, the country has become a forerunner in industrial innovations in textile circulation (Kamppuri et al., 2021) in line with the European Green Deal (2022) policies that aim to tackle climate change issues and increase circularity. The European Green Deal mobilizes industries towards a CE and promotes circular design of long-lasting products that can be reused, repaired, and recycled. Special attention in the European Green Deal was directed towards the textile industry, as it is a resource-intensive sector.

This study contributes to the development of a novel categorisation of circularity catalysing drivers and a new understanding of how they can advance circularity among the actors of an industrial ecosystem. These contributions add to CE ecosystem research (particularly regarding industrial and business ecosystems), CE driver research, emerging research on CEEs and their transformation (Aarikka-Stenroos et al., 2021; Asgari & Asgari, 2021; Bocken et al., 2016; Parida et al., 2019), and general research on the CE in the textile industry. The contributions also provide pragmatic insights and guidance for business practitioners, companies, policymakers, and other public actors in their attempts to implement circularity and reorganize industrial value chains and social systems.

This chapter continues with a literature review on the circular textile industry emphasising the ecosystem approach and potential drivers. This section is followed by a description of the methodological approaches taken to the qualitative data collection and analysis. The results section presents diverse catalysts found in the Finnish textile industry and is followed by a section that summarizes and discusses the findings. Finally, a conclusions section summarizes the research contributions to the theory and practice.

Theoretical background

Textile industry to be catalysed toward the circular economy

The textile industry is recognized as one of the most waste-generating industries globally, and consequently research has indicated diverse rationales on why and how it could transform toward greater circularity (Filho et al., 2019; Franco, 2017; Hole & Hole, 2019). According to industrial reports in 2021, most textiles (73%) are produced for the fashion and clothing industry, followed by technical and household textiles (Grandviewresearch, 2021). The textile market is projected to grow by up to 4% in the period 2022–2030 (Grandviewresearch, 2021).

The typical linear life cycle of a consumer textile product consists of the following five steps: (1) naturally grown or manufactured fibres are spun into yarn, (2) yarns are constructed into fabric then treated with dyes, (3) fabrics are cut, sewn, and trimmed into a product, (4) finished garments are distributed to storage and retail stores and eventually sold to consumers, and (5) in the post-usage phase, textiles are discarded, used as landfill, or are incinerated (Ellen MacArthur Foundation, 2017). Textile production is far from being environmentally viable since it requires enormous volumes of chemicals, water, pesticides, and energy (Bick et al., 2018; Boström & Micheletti, 2016; Šajn, 2019). For instance, the production of petroleum-based polyester fibres utilizes fossil resources and large amounts of chemicals, causing significant carbon dioxide emissions (Bick et al., 2018; Šajn, 2019; Sandin & Peters, 2018). Pesticides utilized for cotton cultivation tend to cause soil depletion and they leak into the waterways, creating threats to freshwater bodies (Boström & Micheletti, 2016; Koszewska, 2018).

Due to the environmental impact of the textile industry, companies and institutional actors are increasingly attempting to transform the industry toward a more circular-operating mode (Filho et al., 2019; Franco, 2017; Moretto et al., 2018). An efficient system of textile circulation requires taking new approaches to textile design, prolonging the textile life cycle, and treating textiles as recyclable raw material instead of waste (European Environment Agency, 2017; Koszewska, 2018). Consequently, industry actors are searching for ways to increase circularity through the transformation of manufacturing operations that enable fibres and textiles to circulate as many times as possible, looping back to different parts of the value chain until the processes of reusing or recycling are no longer technologically, environmentally, or economically feasible (Kessler et al., 2021; Sandin & Peters, 2018; Snoek, 2017).

To address environmental goals and CE logic, a consumer can contribute to circularity by reducing the consumption of textile products through an extension of their lifetime (Levänen et al., 2021). However, worn-out textile garments need to be disposed of eventually. Textile circulation begins when a user places the textile product into a textile waste collection bin for reprocessing or donates it to a nonprofit organisation for resale (Fontell & Heikkilä, 2017). Textile reuse also prolongs the life cycle of a textile product, as the product finds a new user through secondhand boutiques, flea markets, online marketplaces, or renting services (Fontell & Heikkilä, 2017; Joung & Park-Poaps, 2013; Levänen et al., 2021). A crucial part of the textile circulation is a sorting

process that determines whether the textile is reusable, nonreusable but recyclable, or no longer suitable for circulation (Fontell & Heikkilä, 2017; Karell & Niinimäki, 2019; Sandin & Peters, 2018). Textile recycling embraces processes from gathering and sorting used textiles to cutting them into fibre that goes through a mechanical, chemical, thermal recycling, or a combination of these processes (Piribauer & Bartl, 2019; Sandin & Peters, 2018). However, low-quality textiles that are not, for instance, suitable for mechanical recycling or cannot maintain their quality after recycling (Karell & Niinimäki, 2019), can create technological challenges. Even though textiles can pass through multiple cycles of remanufacturing, at a certain point, these textile fibres become unusable for recycling and are consequently discarded at municipal waste points (Kessler et al., 2021; Sandin & Peters, 2018).

From a value chain perspective, conventional textile production is shaped as a global supply chain with production outsourced to developing countries and most consumers in developed markets (Boström & Micheletti, 2016; Fontell & Heikkilä, 2017). The textile industry in developed countries is focused on localized production of high-quality products. However, within the past decade, European countries have begun to introduce manufacturing lines to reprocess used textiles locally due to high volumes of textile waste (Yousef et al., 2020), technological advancement (Franco, 2017; Jia et al., 2020), an issue of carbon dioxide emission during textile production and shipping used textiles back to developing counties for recycling (Moretto et al., 2018; Stanescu, 2021), and the consumer market demand for environmentally sound and ethically produced textiles (e.g., Desore & Narula, 2018; Ozdamar Ertekin & Atik, 2015). Besides the introduction of the European Green Deal (2022), the CE for textiles is actively promoted by the European Commission and the Parliament through its strategy "to achieve a carbon-neutral, environmentally sustainable, toxic-free and fully circular economy by 2050" (European Parliament, 2022).

Applying the ecosystem theory lens to understand circulation within the textile industry

The implementation of textile circularity requires the holistic involvement of various actors from businesses and society. The desired circular textile flow occurs in a complex industrial value chain and a system of networked business-to-business (B2B) companies that produce and supply textile-based products. However, this flow within the textile industry involves many other societal actors, such as nongovernmental (NGO) and nonprofit organisations, governmental institutions, consumers, and social activists (de Oliveira Neto et al., 2021; Fontell & Heikkilä, 2017; Rovanto & Bask, 2022; Staicu & Pop, 2018). Thus, it is relevant to consider all directly or indirectly involved actors on a system level (Parida et al., 2019). In this chapter, the textile industry is approached as an ecosystem of diverse actors who can contribute to textile circulation and whose actions need to be catalysed. The ecosystem approach allows researchers to examine complex industrial systems of interacting actors that are bound together through interdependencies and coevolutionary patterns (Aarikka-Stenroos & Ritala, 2017; Parida et al., 2019).

The CEE implies multiple complementary actors pursuing system-level goals of reduction, reuse, and recycling of materials (Aarikka-Stenroos et al., 2021). A CEE typically is composed of very diverse actors, varying from industrial actors (companies) and public and governmental actors, such as cities, municipalities, and ministries, to universities, nonprofit organisations, and citizen consumers (Aarikka-Stenroos et al., 2021; Staicu & Pop, 2018; Uusikartano et al., 2020). These very diverse CEE types differ regarding their actor setting and circularity goal (Aarikka-Stenroos et al., 2021). For example, circular industrial ecosystems refer to a regional community of hierarchically independent actors who sustainably produce industrial goods and services in

symbiotic collaboration and resource use. Moreover, power is distributed differently in circular industrial ecosystems than in circular business ecosystems, where a set of actors enable the core company's business model implementation by collectively delivering a sustainable value offering by resource recycling, reuse, and/or reduction. Consequently, the structure and organisation of CEEs vary, as they can be either developed around a focal actor that orchestrates actions taken by other actors (e.g., a company managing its circular value chain) or organised among horizontally distributed actors (e.g., an alliance of textile producers seeking to manifest their circular processes) (Aarikka-Stenroos et al., 2021).

Regarding the textile industry, the CEE "aims to keep most post-consumed textile materials in the re-use cycles or recycle them instead of textile waste being incinerated or ending up in landfill. The key objective should be to use recycled textile materials for purposes that regenerate maximum value" (Fontell & Heikkilä, 2017, p. 18). Thus, facilitation of CEE for textile reprocessing requires the development of a network of interacting actors that enables, for instance, circularity of used textile products, information exchange, or facilitation of technological processes, at both national and international levels. The joint actions and system-level goals of the CEE in textile recycling may be focused on the following: (1) the flow of materials (cf. Joung & Park-Poaps, 2013; Levänen et al., 2021; Sandin & Peters, 2018); (2) the flow of knowledge, for example, how textiles can be technically remanufactured or how this process can be framed into a business model (Fontell & Heikkilä, 2017; Koszewska, 2018; Piribauer & Bartl, 2019); and (3) the flow of economic value, for example, profit generation from circulating textiles (Chen et al., 2021; Fischer & Pascucci, 2017; Rizos et al., 2016). Since we are interested in the actors and related catalysts that cause textiles to circulate, the driving catalysts and conceptual approach to their examination are discussed further.

Driving catalysts for the textile CEE

Most research regarding CE refers to the barriers and drivers that shape the boundaries of a system in different industrial settings (e.g., Kirchherr et al., 2018; Ranta et al., 2018; Tura et al., 2019). These studies indicate CE driving mechanisms for business model innovations, novel national and regional regulatory frameworks, consumer acceptance and awareness, and technological infrastructures (Aloini et al., 2020; Kirchherr et al., 2018; Ranta et al., 2018). As regards the CE in the textile industry specifically, drivers may include employees' initiatives (Jia et al., 2020), a favourable organisational culture (Rovanto & Finne, 2022), governmental incentives (Fischer & Pascucci, 2017), growing trends towards conscious consumption (Han et al., 2017; Salmi & Kaipia, 2022), consumer market demand for environmental solutions (Desore & Narula, 2018), and the ethical commitment of business leaders to sustainability (Niinimäki, 2010). In contrast, barriers to the CE in textile utilisation are more variable; there is a lack of clear corporate strategy and sustainability vision on the part of the supply change actors (Paras et al., 2018), financial challenges to making a change towards more sustainable production, especially for small-sized companies (Rizos et al., 2016; Snoek, 2017), insufficient enforcing regulations for the circularity of manufacturing processes (Perry et al., 2015), low technological capabilities or skills (e.g., Aloini et al., 2020; Rizos et al., 2016), limited availability of recycled materials and sustainable product design (Salmi & Kaipia, 2022), and consumer-driven barriers rooted in purchasing decision-making (Desore & Narula, 2018).

This chapter refers to a catalyst approach, this being a concept that embraces the systemic, developmental, and transformative nature of the processes and variety of the process results or outcomes (Cabell & Valsiner, 2013). Therefore, it is suitable to reflect complex and interdependent

relations in the industrial ecosystem. A catalyst can conceptualize specific enablers and mechanisms that support a background ecosystem to create the conditions necessary to facilitate new processes within this system, its transformation, and other changes (Uriko, 2020). This chapter explores the catalysts necessary to enable textile and value flow in the ecosystem of textile recycling, reusing, and resale. The empirical case setting and research methods are discussed next.

Research design and data collection

This study is methodologically framed by case theory to address the complexity of the explored phenomenon. Case theory, in contrast to case study research (e.g., Yin, 2011), embraces an expanded version of the case study and explores a certain case to generalize to a broader scientific area (Gummesson, 2017). Case theory allows for both particularisation (understanding of a particular case) and generalisation (knowledge innovation that can be compared to other cases or create a background for theory generation) (Gummesson, 2017). We chose an extensive single case, namely the Finnish textile industry ecosystem pursuing circularity, as this design enabled us to map the relevant actors contributing to the circularity of the industry and identify catalysts for their contributions. Finland is a fruitful European context for the study of textile circulation, as it hosts several companies developing fibre innovations (e.g., cellulose-based fibres) and examining the commercial potential of recycled textiles (Pylkkänen, 2022). Additionally, Finland has set ambitious goals to begin the separate collection of consumer textiles by 2023 (Gädda, 2021), which can serve as a benchmark practice for other countries in Europe and globally.

Our research design allows us to address the complexity of the focal ecosystem of the Finnish textile industry by studying numerous involved actors and their links and interactions in a dynamic context to develop a theoretical understanding of circularity catalysts. A central aim of the data collection was to capture the multiple perspectives of the ecosystem actors involved (companies, research institutes, NGOs, etc.) and explore catalysts. Empirical data was collected from multiple sources during the period from March 2019 to September 2021. Table 4.1 provides a summary of the data set, ranging from workshops to interviews and media data.

Each interview lasted approximately 70 minutes. The interviews were recorded and transcribed with the permission of the interviewees. The informants were also able to check and validate their transcribed interviews afterwards. The interviews included questions concerning the four following key themes: (1) company or organisation activities and technologies enabling CE and their role in the national ecosystem, (2) partnering actors and their role and importance for the facilitation of CE processes as well as actors missing from the system, (3) challenges to and accelerators of CE implementation, and (4) specific enablers of and conditions aiding CE facilitation. The field notes included remarks made at workshops, webinars, and panel discussions, concerning, for example, the ecological and social impacts of linear textile production, organising sustainable textile production and circulation (e.g., end-of-life textile collection and sorting), and turning textile recycling and novel recycled or bio-based fibres into a business, as well as remarks about the technical processes showcased at the tours of processing premises. The interviews and textual data of the field notes were analysed through content analysis during which the key themes and expressions related to the research objectives were identified (Duriau et al., 2007; Zhang & Wildemuth, 2009). The data from each interview was examined to find details about the main actors, conditions, motivations, and enablers of CE implementation and compared across interviews and field notes. After comparison, concurring themes and similarities were identified, allowing for us to determine and categorize the key catalysts for textile circulation within the national ecosystem. For instance, interviewees' observations about organisational management and

Table 4.1 Empirical data sources and methods of data collection

Data types and methods of data collection	*Data sources*	*Description*
Interviews	Interviews with ecosystem actors ($N = 14$; lasting approx. 70 minutes each)	Ecosystem actors and interviewees • Municipal waste management organisation (Circular economy specialist) • Technical research centre, governmental nonprofit organisation (Senior scientist, project manager) • Non-profit organisation, consumer textile management (Workplace counsellor) • Textile collecting and reselling nonprofit organisation (Communication specialist and clothing collection manager) • Textile, fashion, and apparel industry employers' association organisation (CE specialist) • University of Applied Science A (Textile CE expert) • University of Applied Science B (Development manager) • University C (Project researcher, recycled textile fibre specialist) • Medium-sized textile manufacturing company (Corporate responsibility manager) • Small-sized textile manufacturing company (project and management representative) • Small-sized textile recycling, technology provider company (Research professor, founding member) • Small-sized textile recycling company (B2B) (Customer relationship manager) • Small-sized clothing rental company (Chief executive officer) • Small-sized CE textile solutions, closed-loop services (B2B) (Chief executive officer and marketing manager)
Field notes	Workshop	03.2019 Growth from the Circular Economy – a workshop for textile industry actors (VTT Technical Research Centre of Finland, Espoo, Finland).
	Webinar	14.05.2019 Telaketju webinar (Finnish network of textile industry actors promoting textile recycling).
	Panel discussions	09.2019 Oslo Innovation Week 2019. Panel discussion: 'Wood looks good on you': how to build a profitable business around fashion and recycling of textiles.
	Tour of the textile sorting line and fibre laboratory	08.2019 Textile material identification line, Lahti University of Applied Sciences, Finland.
Media data, marketing, and promotion materials	Websites of companies and organisations	Media and promotion materials of 14 organisations participating in the research.
Research reports and publications	Project reports	Fontell, P., & Heikkilä, P. (2017). *Model of circular business ecosystem for textiles*. VTT Technical Research Centre of Finland. Kamppuri, T., Kallio, K., Mäkelä, S. M., & Harlin, A. (2021). *Finland as a forerunner in sustainable and knowledge-based textile industry-Roadmap for 2035*. VTT Technical Research Centre of Finland.
	Press release	Šajn, N. (2019). *Environmental impact of the textile and clothing industry*. European Parliament.

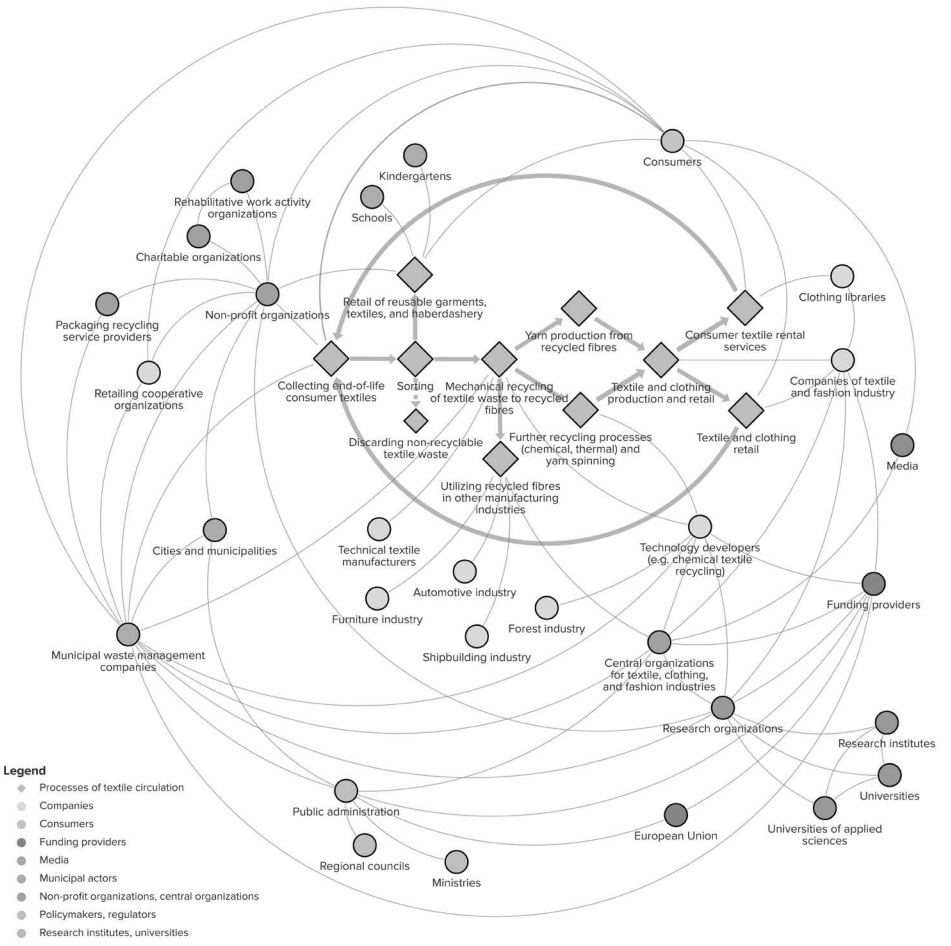

Figure 4.1 Industrial ecosystem for textile circulation: Actor types and relations.

Source: The authors.

culture were framed within the organisational catalysts category, and the technological capabilities discussed were framed within the technological catalysts category. Media and marketing data were used to gain additional insights into the ecosystem actors' roles, operations, and agendas, whereas reports and publications provided further understanding of the status quo of textile and fashion industries and textile circulation both nationally and globally. Our analysis resulted not only in catalyst categorisation, but also the map of the ecosystem actors (see Figure 4.1), depicted with the help of the Kumu.io online mapping platform provided by Kumu Inc., presented in the following section.

Results

Based on the study results, Figure 4.1 maps the CE textile ecosystem in Finland, actor types, and their roles and interconnections. The diamonds in Figure 4.1 depict the necessary processes for the circulation of consumer textiles, from collection and sorting of end-of-life textiles through recycling processes to manufacturing new textile products from recycled fibres. The circles in Figure 4.1

represent diverse actor groups in the ecosystem and both their mutual interlinkages and relation to the circulation processes, as described by the interviewees at the time of data gathering.

According to the empirical data analysis, six key driving catalyst types are perceived by the actors of the Finnish textile CEE are the following: (1) technological catalysts, (2) business catalysts, (3) organisational catalysts, (4) regulatory catalysts, (5) communicational catalysts (visual and linguistic), and (6) ethical catalysts. These catalysts are discussed next.

Technological catalysts

Several of the studied companies already have experience in textile recycling. Thus, diverse material processing as well as digital technologies were identified as technological catalysts enabling recycling or reuse. Modern technologies allow the use of mechanical and chemical recycling or a combination of these methods. For instance, one recycling company considered in this study was created around CE mechanical recycling technological advancement. However, the used textile collection phase remains challenging as it requires the presorting and collection of noncontaminated pieces of textile (e.g., articles without strong odours or mould). Manual sorting is also needed to select pieces that can be resold or have higher market value, such as vintage and branded garments. Several collaboration projects between companies and universities in Finland are working on the design of collection boxes, their strategic location (e.g., closer to consumers), and formulating clear instructions for consumers on the boxes to prevent them leaving textiles that cannot be recycled.

In preparation for recycling, textiles should be sorted into different fractions based on their fibre composition and transferred either to a warehouse or directly to a processing line. Mechanical recycling can be applied to textiles whatever their fibre composition. During mechanical recycling, textile waste is shredded into a processable fibre form that can be used to manufacture raw materials and for further chemical or thermal recycling or for yarn spinning. Mechanically recycled fibre has market potential even though the fibre length is shorter after each recycling process. Chemical recycling is applied when mechanical reprocessing alone does not result in high enough fibre quality, and it has even higher market potential. This recycling type is suitable for cellulose-based fibres and usually applied to cotton and viscose reprocessing. This method has already been tested as a pilot project but scaling up would require further technological development of recycling lines and, consequently, more investment. Implementation of chemical recycling can increase volumes of recycled fibre supplied to the market. This technology also provides significant logistic benefits: textile waste can be processed into the liquid raw material in one location and recovered into textile fibre in another.

Since textile manufacturing and circulation activities involve a tremendous amount of data, the handling of these data can improve the traceability of textile life cycles. The digital tools and software supporting these processes are still being piloted through partnerships between companies and universities. For instance, exploration is ongoing of the creation of a digital product passport that can contain information about materials, chemicals, and processes included in a product's life cycle and instructions for further recycling. Product traceability can allow a holistic approach to business model development whereby certain products circulate in small-scale closed loops, for instance in a B2B sphere. As the interviewed customer relationship manager of the textile recycling company has emphasized: "All kinds of digitalisation tools for identification and quality check of materials are needed. Quality check of fibre length, technical specification, laboratories, etc. This kind of digitalisation is needed in the future". Close collaboration with the software/hardware industry is also required to facilitate textile identification processes during the sorting of used garments. However, many such projects are still in the piloting stage. Digital catalysts are also needed for better online platform development for companies that rent

out clothing for consumers and businesses (e.g., workwear). One example of a digital catalyst is virtual fitting for online stores and clothing rentals to reduce the amount of returned clothing.

Business catalysts

Previous research and the results of this study indicate an increased demand in consumer markets for sustainable solutions in the fashion and textile industries (Desore & Narula, 2018; Ozdamar Ertekin & Atik, 2015; Vehmas et al., 2018). This demand is driven primarily by the influence of the mass media, growing consumer consciousness, more responsible consumption, and trends towards the use of secondhand clothing. Modern consumers expect to donate or discard textiles for reuse and recycling. However, they also expect that organisations will collect used textiles at convenient locations. Sorting and collection of used garments are becoming the key processes that define future faith in textile waste. These activities need to be efficiently performed to demonstrate economic viability, offering an opportunity for business organisations – especially small-sized companies – to integrate sorting and collection into their value chains or develop new business models to manage the logistics of used textiles.

According to evidence generated by the companies participating in this research, the current textile production infrastructure can be modified to integrate textile recycling lines into existing manufacturing processes if the companies realize economic value. Since textile recycling is a relatively new business, companies can tackle the associated uncertainty through collaboration and involvement in projects with NGOs and universities to obtain technological solutions and financial support. Conventionally, such shared-purpose collaboration involves many business and institutional partners that not only share financial risks but also benefit from innovations, solutions, networking, and knowledge sharing (Ritzén & Sandström, 2017). Thus, changes in the textile circulation ecosystem may be accomplished only when multiple actors collaborate with the aim of redefining the value chain, as the corporate responsibility manager of the textile manufacturing company points out: "When you have four or five players, then it leads to an equal business ecosystem, and one must be always the leader". However, according to the current interviews, finding investors in Finland may still be a challenge for circularity businesses, although many projects find support from the government and international organisations. Thus, commercialisation of innovations and active promotion of recycled material usage across industries is required.

Organisational catalysts

Leadership and strategic management are among the drivers for sustainable innovations (e.g., Niinimäki, 2010). Business leaders and employees frequently take proactive roles in CE implementation, especially when their businesses are connected to the textile industry. According to the interviews, sustainable initiatives may impact the whole network of business actors when a strategically important company changes its business processes. A reactive response to market changes towards circularity may be caused by opinion leaders and institutional actors, for instance, input from universities. According to the interviews, Finnish universities attempt to disseminate knowledge on CE principles to business and consumer markets and to promote multi-actor projects and collaboration. Businesses benefit from this collaboration by retaining ownership of the innovation developed in the projects. Another role of the universities is to integrate knowledge of the CE into the curriculum of different subjects that are taught, thus leading to an increase awareness of circularity-enabling technologies and the CE in business and consumption.

Organisational culture also serves as a catalyst for circularity if it promotes open-mindedness and values environmental and social responsibility (Kwarteng et al., 2021), as many Finnish

companies do (Koistinen et al., 2022; Rovanto & Finne, 2022). To promote innovations and initiatives in organisations, internal and external communications favourable to knowledge and the exchange of ideas need to be established. However, different countries have different attitudes toward circularity due to their culture, legislation, and business principles. Therefore, promotion of CE at the international level may be significant for international business and institutions to share best practices and knowledge.

Regulatory catalysts

Most of the interviewed research participants agreed that governmental regulations favouring circularity are a crucial catalyst, institutionalising and legitimising circularity. These may concern, for instance, collection of end-of-life textiles that can make a larger raw material flow for recycling. However, current textile CE legislation is based on waste management regulations, which is controversial considering that the CE aims to recover raw materials. For instance, as mentioned by the customer relationship manager of the textile recycling company, the reason that some recycling companies cannot deal with household textiles in Finland is "the law of restrictions related to waste management. Municipalities and the companies of regional waste management are responsible for household materials." Therefore, the waste status of end-of-life textiles should be changed to address this issue. Concurrently, this challenge is on the agenda at the EU level as an interviewee of the textile manufacturing company clarifies: "The EU is changing legislation for waste management, meaning all textiles in the European community must be recycled or collected separately so they will no longer be incinerated or used as landfill" (see also European Green Deal, 2022). Sustainable choices can also be promoted with tax regulation in both industry and consumer markets, for instance, by lowering the value-added tax of recycled textile and fibres.

Introduction of textile standardisation and labelling on the global level could enhance awareness of recycled materials and create a market for raw material with predefined classifications (e.g., origin of fibres, quality, etc.). Standardisation can tackle the challenge of material properties recognition across industries, where business actors can find various utilisations of recycled textiles, such as in the construction industry (Christensen, 2021). However, textile-to-textile recycling remains the key option, and this demands a specific approach to textile design that should align with the standards for the future recycling.

Regulations can also regard the import and export of textiles, their quality, and the data availability of products entering the EU. This global challenge may also concern the traceability of textile garments and brand protection. However, traceability raises the questions of what information may be included in a product passport and who can access it. Despite the benefits of standardisation and product quality criteria development in respect to circularity, such development may affect free trade and product movement across borders. Thus, these issues require deeper consideration at the international level.

Communication: Linguistic and visual catalysts

Our case analysis also exposed the importance of communication through visual images and aesthetics, as well as linguistic means that could all catalyse textile circulation. Mass media actively creates an awareness for consumers and B2B markets about CE in the textile industry by using understandable language, terms, and visuals (e.g., Han et al., 2017). For instance, the Finnish national news portal Yle has launched documentaries explaining and showcasing CE in different industries. According to our interviews, the efficient promotion of circularity depends on these media delivering a comprehensive message and using a common terminology. For instance, an

interviewed representative of a clothing rental company suggested that terms such as sustainable or responsible garment can come across as vague and misleading, unless it is also clarified exactly which aspects of sustainability or responsibility are actualized in each product. Furthermore, the interviewees from nonprofit organisations emphasized that consumers frequently find it hard to understand the difference between donating and recycling textiles and may not be aware of what happens after a garment is placed in a textile collection box. This issue is important to address to ensure the efficient sorting and separation of clothing that is suitable for donation or resale and that which can be sent for recycling.

Interviewees emphasized that a common understanding of CE among business partners may serve as a catalyst for changes in the value chain. Communication is important in this case so that proactive companies can inform partners of CE opportunities and strategies (Paras et al., 2018). Companies such as the medium-sized textile manufacturing company that participated in this study can set a benchmark for further strategic development of circular processes. Information dissemination about CE in the business world can also be promoted through workshops and seminars for industry representatives, such as those noted in this research. Additionally, universities play a key role in CE knowledge transfer to students – not only through theory, but through research and projects with other institutional and business actors. Public speeches and lectures also increase public interest in circularity.

Diverse visual means were found to be important catalysts. These visual means include images, videos, and graphics that aim to explain technical processes, opportunities for business growth, or sustainable consumption habits (Han et al., 2017). Visualisation, besides delivering a marketing message, can make it easier to understand the number of resources used, processes behind recycling, properties of new products made of recycled materials, and so forth. Visual messages may need to be simplified for consumers that discard textiles. For instance, graphic instructions may be placed on textile collection boxes intended for recycling. However, it is still necessary to develop standardized symbols related to textile disposal across countries for consumers as well as for businesses.

Aesthetics also plays a role in perceptions of circularity (Jia et al., 2020). According to the interviews, conventionally eco-fashion has a reputation for being less visually attractive. New eco-brands aim to tackle this myth through unique design and quality products. The modern fashion industry offers a variety of sustainable clothing that may be desirable for its aesthetics and not only as a conscious consumption choice. Social media and image sharing are an effective means of popularising CE visually. Aesthetics also concerns designing secondhand shops as a point of sale in a way that shifts their reputation from 'flea markets' to 'vintage clothing stores'. The subjectivity of aesthetics may be challenging since the quality, look, and trendiness of donated, reusable garments can vary drastically due to differences in taste, perception, and sentimental value. However, as indicated by studies of Finnish fashion brands, durable, long-lasting clothes with a universal design can preserve their value on the secondhand market (Salmi & Kaipia, 2022).

Ethical catalysts

Catalysts in the circular textile industry may also originate from the ethical perspectives of consumers and business managers. Increased awareness of ethical consumption and recycling has created a market demand for sustainable solutions, where business organisations bear responsibility to produce environmentally and socially viable business offers. For instance, society has expectations that business and institutional actors will address the climate change issues that also concern fashion industry and textile production (Niinimäki et al., 2020; Peters et al., 2015; Vehmas et al., 2018). The ethical production of textiles and ethical fashion has become mainstream

rather than an added-value activity carried out by companies (e.g., Brydges, 2021; Mishra et al., 2020; Perry et al., 2015). Pressure to find ethical solutions also originates from industrial ecosystems, where actors strive to take the leadership in addressing environmental issues, and competitors must follow business trends. Implementation of CE in the textile industry is becoming an ethical choice since the business mindset is also changing from satisfying shareholders towards achieving environmental, social, and economic sustainability. For some companies participating in this research, sustainability and business ethics are at the core of their business strategy, possibly explaining their longevity on the market.

The interview data showed that an efficient CEE is based on trust and transparency among its actors due to a need for collaboration and to follow common ethical goals. Trust development is especially viable for B2B interaction as some CE value chains may require new actors to enter the industrial ecosystems to facilitate infrastructure. Additionally, ensuring business activities are transparent increases the popularisation of circularity among business partners and manifests the trustworthiness of the company as well as strengthening its image. As was emphasized in the interviews, ecosystem actors need to realize common business and societal goals toward sustainability, otherwise the partnership cannot be fruitful.

The popularisation of conscious consumption influences changes in consumer behaviour and emphasizes the importance of individual choices, which make consumers a part of sustainable solutions (Desore & Narula, 2018). According to the interviewed nonprofit organisations and apparel industry employers' association representatives, consumers in Finland are keener to choose ethically produced textiles with sustainable features including the use of recycled materials. Although some misconceptions still exist regarding the quality of recycled products, these preconceptions can be overcome through the promotion of eco-fashion, design, and communication about fabric properties.

CE inhibitors

Although this research is focused on catalysts as positive drivers of circularity, our study also uncovered a set of the key inhibitors slowing CE development. First, technologies performing textile recycling have been introduced to the market only recently, and some have not yet reached an advanced level of technological readiness; they are still in the testing or piloting phase. Novel technologies cannot yet guarantee a high volume of recycling and flawless processes (De Jesus & Mendonça, 2018). According to the empirical data, technologies for recycling complex composition textiles, such as multilayered textiles, textiles with highly varying fibre compositions, or elastic knits are still in high demand for efficient recycling. Current technological imperfections require the manual sorting of textile waste, which further inhibits the CE as this is a work-intensive activity. This type of labour does not require specific training but organising this activity in developed industrial countries such as Finland is challenging due to high labour costs. Automatisation and digital support of sorting (robotics, AI and machine vision, and tracking), storing, and collecting information about textile articles would be a solution; no such solutions have yet reached a high level of technological readiness.

Legal regulations help to promote the circularity in business and consumer markets that forces companies to take proactive actions (Gädda, 2021). However, incentives are still lacking in this process. Companies may pursue CE implementation as forced changes in the industries but receive little support of the government with knowledge and finances. In this case, collaboration with universities and research institutions helps to tackle uncertainty and lack of knowledge, but financial incentives could make businesses more motivated toward circularity (Fischer & Pascucci, 2017). Lack of both knowledge and communication may also result in the

misunderstanding of CE processes among value chain actors (Paras et al., 2018). As emphasized in the interviews, partnering companies may underestimate the opportunities of CE if they do not show immediate short-term economic results. Thus, the economic viability of CE should be viewed from a long-term perspective and considered in the future strategies of business organisations. Communication about circularity requires a stronger representation inside organisations and should be incorporated into organisational culture, as well. Ethical and moral motives may serve as enablers of change in the organisation towards more sustainability, but employees and managerial staff need to understand the reasons, motivations for, and benefits of CE.

Inhibiting factors related to the consumer markets may include the predominant assumption about the low quality of recycled or reused products. Additionally, a misunderstanding about the sustainable qualities of products can prevent consumers from purchasing. Thus, there is clearly a need for communication and information dissemination about sustainability in general, the issues circularity aims to solve, and how and where the recycled products are produced (Singh & Giacosa, 2018). Although conscious consumption is increasingly popular (Desore & Narula, 2018), companies should put more effort into emphasising the aesthetics and practicality of products with sustainable characteristics.

Summary and discussion

This study identified and conceptualized the ecosystem and driving catalysts needed for textile circulation. Table 4.2 summarizes the identified catalysts and also provides a brief overview of how they catalyse circulation. In addition to the catalysts, our findings showcase the interaction and complementarity of business, institutional, and public actors acting with the common purpose of reducing textile waste and maintaining the routine of textile recycling or reuse (e.g., Aarikka-Stenroos & Ritala, 2017; Aarikka-Stenroos et al., 2021; Fontell & Heikkilä, 2017; Uusikartano et al., 2020).

According to the findings, technological progress in the textile industry can be a driving force for new business models and changes in manufacturing processes. Many modern textile recycling technologies have been introduced in the EU to turn textile waste into raw materials (Franco, 2017; Koszewska, 2018; Yousef et al., 2020). Mechanical, chemical, and thermal recycling processes and combinations of these are among the most common technological activities enabling production of yarn and fibres from used textiles (Piribauer & Bartl, 2019; Sandin & Peters, 2018). Chemical recycling has more commercial potential as it can often produce yarns with a higher quality than those achieved with mechanically recycled fibres alone. Locating the recycling lines in the EU brings them closer to the consumer market and reduces distances for logistics aiming to tackle environmental issues (Boström & Micheletti, 2016; Fontell & Heikkilä, 2017). Location may affect textile waste and end-of-life textile collection as well as the sorting and delivery of used articles for recycling. Sorting is a crucial process in the value chain since not all textiles are recyclable (Karell & Niinimäki, 2019; Sandin & Peters, 2018). Digital tools could be helpful in monitoring the quality and properties of textiles. Digital solutions for information management about matters such as the usage (especially in the industrial sphere) and properties for recycling of textiles are at a development stage. Some digital platforms can advance clothing resale and renting services by placing points of sale online and introducing virtual fitting.

Although recycling technologies are a powerful catalyst, technology development cannot fully fuel the needed change in the textile ecosystem, and a combination of diverse, interlinked catalysts is needed. New technologies are associated with risks and unlikely to be implemented and commercialized without sufficient investments, regulatory support, or strategic leadership. Economic value can be a strong motivation for ecosystem actors to implement CE principles in

Table 4.2 Catalysts for textile circulation in the CEE

Catalysts for textile circulation		*Rationale: what catalysts do/how they catalyse*
Technological catalysts for recycling and reuse	Textile waste and end-of-life textile collection and sorting	Developing and serving collection points can be framed as a business model. Automatisation of sorting processes allows economies of scale to be achieved. The processes of sorting and identifying fibre types can be integrated into a business model.
	New textile recycling technologies and updates to existing production lines	Technological development will help improve recycling manufacturing facilities and the implementation of innovations in existing production lines. Different methods of textile recycling are developing and becoming more available for commercialisation.
	Digital solutions	Technical support for the processes related to recycling, renting, and tracking textiles is actively developing and requires more collaboration with the IT industry and new digital platforms.
Business catalysts	CE business models	The processes of resale, reuse, and recycling demand novel approaches to business model development.
	Changes to existing infrastructure	Companies can change their existing infrastructure to implement recycling processes that can add value to their business activities.
	Cross-sector collaboration	Since many business innovations in the textile industry are in the developing stage, more commercialisation of technologies and collaboration with business and institutional actors are required to develop sustainable solutions and share business risks.
Organisational catalysts	Proactive and reactive response to market demand	CE principles may be implemented following managers' initiatives for sustainability and/or as a reaction to market demand or changes in the business networks.
	Organisational culture	An organisational culture that promotes innovations and idea sharing can create favourable conditions for CE implementation in organisations.
Regulatory catalysts	International and national/regional regulations on textile reuse and recycling	Changes to local and international regulations towards CE in the textile industry support the strategic orientation of businesses towards circularity and influence consumer behaviour. The legal standardisation of textile characteristics labelling can simplify textile recognition for recycling but requires the development of international standards and labels.
Communication catalysts (linguistic and visual catalysts)	Linguistic: terms, words, and verbal discourse; shared understanding of words	Active communication and a common terminology for and understanding of circularity may increase collaboration between business and institutional actors for CE development.
	Visuals: figures, images, colours, symbols, logos, and other visual objects	A visual marketing message may be an efficient means to promote instructions about recycling and reuse of textiles. Visualisation is important for the aesthetic perception of eco-fashion and to enhance demand for recyclable products.
Ethical catalysts	Sustainability and ethics in business processes	Changes towards the CE may be based on ethical business practices and strategies to develop sustainable business solutions.
	Conscious consumption	The popularisation of conscious consumption and ethical fashion have become triggers for ethically produced textiles and increased consumer interest in recycling, reuse, and resale of garments.

the business processes (e.g., Aloini et al., 2020). However, engagement in the recycling business can be an answer to the consumer market demand for sustainable solutions (Desore & Narula, 2018; Ozdamar Ertekin & Atik, 2015). Companies can collaborate with nonprofit organisations and other institutions to share the risks of establishing new value chains. Such cross-sector interaction can be facilitated through collaboration with universities and research groups.

Favourable governmental regulations are among the key catalysts for the textile CEE. For instance, the European Parliament has introduced the European Green Deal (2022) aiming to address environmental issues, while the European Commission is promoting a CE strategy (European Parliament, 2022). Eventually, strategic regulations on the CE will become legislation at the local level (Gädda, 2021), forcing companies to start adopting new strategies to face future changes. Several companies dealing with textiles in Finland are already engaged in piloting projects regarding textile recycling to scrutinise business opportunities and correspond to regulatory changes.

The CE may be catalysed by a favourable organisational culture that allows the communication of shared values and understandings (Jia et al., 2020). However, changes such as the introduction of circularity may affect not only one business organisation but the whole network of involved actors, possibly causing a redefinition of the business network and the involvement of nontraditional actors such as universities, nonprofit organisations, and other institutions (Ritzén & Sandström, 2017). Failure to understand the strategic importance of circularity among the value chain actors may create a barrier to CE implementation (e.g., Paras et al., 2018). Communication becomes a necessary catalyst for these processes, since a common understanding and terminology of CE principles, knowledge exchange, and setting common goals are vital for managerial processes across the ecosystem. However, communication may involve not only B2B information sharing, but also address the consumer market by popularising circularity through marketing messages. The aesthetic approach to and visualisation of products made of recycled materials may appeal to conscious consumers and tackle the dominant assumptions about these products' quality (e.g., Singh & Giacosa, 2018).

Since the consumer market is seeing a rise in conscious consumption (Desore & Narula, 2018; Peters et al., 2015), companies are responding not only with sustainable solutions but by taking a proactive stance to manifest their sustainability and ethical approach (Niinimäki et al., 2020). Ethical (environmentally and socially sound) fashion is becoming a new normal and cannot be ignored by the textile industry, which is conventionally among the most polluting and unethical of sectors (Bick et al., 2018; Brydges, 2021; Koszewska, 2018; McFall-Johnsen, 2020; Mishra et al., 2020). Thus, circularity is an ethical approach to the management of business activities. For some companies, embedding business ethics in their management mindset may be a catalyst for CE since they attempt to balance economic value with environmental and social concerns. Disseminating CE principles across an ecosystem also demands actors' close collaboration based on ethical values such as transparency of business processes, trust, and shared ethical goals.

Conclusions

This extensive study explores diverse actors contributing to the circularity of the textile industry as a CEE and the key catalysts that facilitate and create favourable conditions for textile circulation. It uncovers a variety of perspectives and the voices of different ecosystem actors that allow us to capture and conceptualize six major catalyst types (technology, business, organisation, communication, regulation, and ethics) and explore how these catalysts act as mechanisms. Additionally, the findings allow us to map a CEE with complementary actors whose actions need to be catalysed to develop a more circular textile industry. Therefore, this study adds to the literature on

CEEs (Aarikka-Stenroos et al., 2021; Parida et al., 2019). Utilisation of the concept of catalysts has cross-disciplinary implications. The concept theoretically and metaphorically reflects enablers and conditions that aid in facilitating ecosystems (Cabell & Valsiner, 2013; Valsiner, 2013). Specifically, this study increases our understanding of the industry ecosystem and needed catalysts for textile circulation (Fischer & Pascucci, 2017; Franco, 2017). Contributions are also made to the studies focusing on drivers and barriers in CE (Kirchherr et al., 2018; Ranta et al., 2018; Tura et al., 2019). This study also has pragmatic implications for business managers, industry developers, nonprofit organisations, investors, governmental bodies, and regulators on how they can catalyse industry transformation toward circularity (Table 4.2) and whom they should involve (Figure 4.1).

We acknowledge that our study has several limitations. First, we examined the Finnish-based national textile-oriented actor ecosystem, although research on other industries and geographic and institutional locations may provide different results. This study also relies on a limited number of interviews. However, analysis of multiple data sources adds to the trustworthiness of the research findings. Finally, Figure 4.1 may lack some actors, but it represents the most prominent actors in the studied ecosystem at the time of data collection.

Regarding future research avenues, more understanding of the multiple-actor systems enabling circular or resource-efficient raw material flows is needed. Furthermore, research is needed to identify diverse driving catalysts for circularity that may be hidden in the international business and sociocultural settings.

Educational content

- A textile circulation ecosystem can be driven by technological, organisational, regulatory, communication, and ethical catalysts originating from business, institutional, and social spheres.
- The conceptualisation of a catalyst extends our understanding of CE drivers. In this case, catalysts embrace favourable conditions and enablers of the actors' ecosystem targeting CE implementation.

Discussion questions:

1 In what ways can the life cycle of textile fibres and consumer textile products be extended?
2 What measures can different actor groups take within a business or collaboration setting to promote circularity in the textile industry?
3 What are the major motivating factors influencing companies' proactive actions toward CE in the textile industry?

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