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A Potential Method For Adaption of Circular Economy Into the Textile and Apparel Industry?

Döngüsel Ekonominin Tekstil ve Hazir Giyim Endüstrilerine Uyarlanmasi İçin Bir Potansiyel Yöntem?

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Döngüsel Ekonomi,
Tekstil,
Hazır Giyim,
Sürdürülebilir Üretim,
Çevresel Etkiler

ÖZ

Sera gazı emisyonlarındaki artış, iklim değişikliğinin yol açtığı kırılganlıklar ve doğal kaynakların hızla tükenmesi, şirketleri doğrusal ekonomiden döngüsel ekonomi modeline geçişe zorlamaktadır. Mevcut doğrusal model, tekstil ürünlerinin üretim, kullanım ve bertaraf aşamalarında sürdürülemez sonuçlar doğurmakta; 2023 yılında küresel elyaf üretiminin 124 milyon tona ulaşması ve her yıl 90–100 milyar giysi üretilmesi bu baskıyı artırmaktadır. Üretilen giysilerin yaklaşık 92 milyon tonunun çöplüklere gitmesi, tekstil atıklarının küresel depolama alanlarının en az %7'sini oluşturduğunu göstermektedir. Lif ve kumaş üretiminden başlayan ve fosil yakıtlara yoğun şekilde bağımlı olan bu süreçlerin, kaynak tüketimi ve çevresel etki açısından çok yüksek maliyetler yarattığı; sektörün küresel CO_2 emisyonlarının %3'ünden ve su kirliliğinin %20'sinden sorumlu olduğu bilinmektedir. Döngüsel tekstil modeli, ürün yaşam döngüsünün sonunda onarım, yeniden kullanım ve geri dönüşüm yoluyla malzemelerin ekonomik sistem içinde tutulmasını hedeflemekte ve sürdürülebilir büyüme, doğal kaynakların korunması ve ekonomik refah açısından stratejik bir zorunluluk olarak ortaya çıkmaktadır. Bu makale, tekstil ve hazır giyim işletmelerinin döngüsellik ve sürdürülebilirlik ilkelerini uygulayabileceği yöntemleri incelemekte; başarılı bir dönüşümün, işletme içi süreçlerin yanı sıra belediyeler, STK'lar ve tüketici tutumlarının desteğine bağlı olduğunu ortaya koymaktadır.

KEYWORDS

Circular Economy,
Textiles,
Apparel,
Sustainable Production,
Environmental Impact

ABSTRACT

Rising greenhouse gas emissions, climate-related vulnerabilities, and the depletion of natural resources are compelling companies to shift from a linear to a circular economic model. Within this context, the production, use, and disposal stages of textile products have become clearly unsustainable under the current linear structure. Global fiber production reached a record 124 million tons in 2023, and an estimated 90–100 billion new garments are produced annually. Alarmingly, about 92 million tons of these garments end up in landfills, where textile waste is estimated to account for at least 7% of total global landfill volume. The production chain—from fiber manufacturing to fabric processing—relies heavily on fossil fuels, resulting in significant resource consumption and environmental impact. The sector is known to contribute approximately 3% of global CO_2 emissions and 20% of global water pollution. The circular textile model aims to extend product life and maintain material flows within the economic system through repair, reuse, and recycling at the end of the product lifecycle. This approach is not a passing trend but a necessity for conserving natural resources, ensuring sustainable growth, promoting responsible consumption, and supporting overall economic well-being. This article reviews studies outlining methods through which textile and apparel firms can adopt circularity and sustainability principles. It argues that a secure transition requires coordinated actions at internal, external, and broader environmental levels, and that the speed and success of this transition depend not only on firms' circularity performance but also on the support of municipalities, NGOs, and consumer attitudes.

1. Introduction

The circular economy is an economic model aimed at minimizing waste and making the most of resources. It emphasizes sustainability by promoting the reuse, recycling,

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and regeneration of materials, unlike the traditional linear economy, which follows a "take, make, dispose" approach. This traditional model appears to have reached its physical limitations (Ellen MacArthur Foundation, 2015). It is responsible for generating a total global waste of around 20 billion tonnes every year. This is an estimated figure calculated for the year 2017 (Maalouf & Mavropoulos, 2023) based on material flow analysis. It is supposed that the total waste arising requires the consideration of the entire life cycle of materials and products. These include mining and quarrying wastes (extraction); agricultural and forestry wastes; industry wastes (materials, parts, and product manufacturing); construction and demolition waste; commerce and institutions waste (distribution and services); consumption (households) and MSW (municipal solid waste). The consequences of those wastes on the Earth is huge, no matter it is hazardous or not. They lead to considerable damage on ecosystems and marine life, and pollution on water sources, and contribute to air pollution through greenhouse gases.

In recognition of the constitutional role of the environment together with its functions and interactions within the economic system, the circular economy (CE) has emerged as a promising alternative to the neoclassical economic model (Ghisellini et al., 2016). The concept of the circular economy has evolved over several decades, drawing from various fields and movements focused on sustainability and resource efficiency. The roots of the CE can be traced back to early environmental movements. The idea of "closed-loop" systems emerged. Kenneth Boulding was one of the pioneers promoting recycling and waste reduction for sustainable resource use. He described an alternative paradigm, a closed economy that might also be called a "spaceman" economy. Boulding refused to measure success based on levels of production and consumption and advocates for a measure based on the nature, quality, and total capital stock, including the state of human bodies and minds (Boulding, 1966).

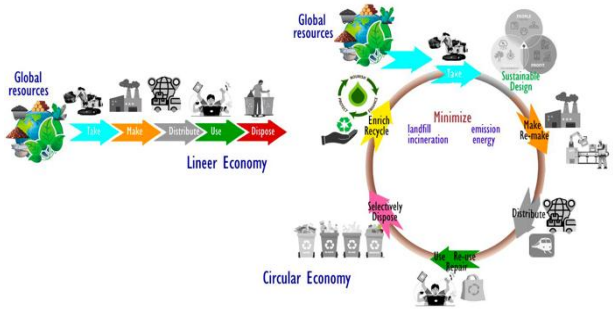


Figure 1. The Concept of Circular Economy and Comparison with the Linear Economy Model (adapted from various sources).

In the 1980s, the concept of Industrial Ecology was introduced, and the rise of eco-design principles encouraged manufacturers to consider the environment. The Earth was perceived as a single spaceship with no unlimited resources, and man had no alternative but to reconnect with the cyclical ecological system that could only provide materials to be reused continuously.

Pearce & Turner (1990) were reported as the first formal user of the term "circular economy" in an economic model for the first time by focusing on the principle that "everything is an input to everything else". The authors criticized the traditional linear economic system and introduced a new economic model, in the name of CE. This model was said to exploit the principles of the first and second laws of thermodynamics. It actually establishes a prominent link between the economy and the environment by incorporating three economic functions of the environment: resource supplier, waste assimilator, and source of utility. In the 2000s, the CE concept attracted great interest and increasing popularity. This approach was highly recognized by the European Union by emphasizing waste reduction and resource efficiency in its policies. The concept of the CE in comparison with the linear economy model is illustrated in Fig.1. As seen in the figure, the CE maintains a closed loop cycle on the base of a regenerative system that aims to maximise product and material utilizations and minimizes the entry and waste of resources, emissions, and expenditure of energy through slowing down, closing, and straightening material and energy circuits. Following the very first definition of Pearce & Turner, various definitions of the CE respecting several concepts have been presented by many researchers. A number of authors have specified resource-oriented definitions and interpretations, emphasising the need to create closed loops of material flows and decrease the consumption of virgin resources and their consequent harmful environmental impacts. They believe that the essential priority of the CE is the reduction of resource consumption, pollution, and waste in each step of the product's life cycle (Rizos, Tuokko, and Behrens, 2017).

A definition by the Ellen MacArthur Foundation (2013) has been one of the most frequently cited definitions that incorporates elements from various disciplines. The CE was defined as "*an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models*."

In the view of the cradle-to-cradle approach and systems thinking, this interpretation of the concept involves the distinction of two different types of materials: materials of biological origin that can return to the biosphere as feedstock (e.g., forest products) and technical materials, which cannot biodegrade and enter the biosphere (e.g., plastics and metals). Under this framework, the circular economy aims to keep both types of these materials at their highest utility and value at all times through careful design, management, and technological innovation (Ellen MacArthur Foundation, 2013; 2015).

At the EU level, the European Commission (2015) has included a description of the concept in its Communication "Closing the loop – An EU Action Plan for the circular economy", which is part of the Circular Economy Package. Specifically, the circular economy is defined as an economy "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimised." A possible shift to a more circular economy would make "an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy". In this context, the EU Action Plan includes a series of measures aimed at addressing the full product cycle from production and consumption to waste management and the market for secondary raw materials.

The CE offers a reliable structure for radically improving the current economic model within the scope of developing a preventive and regenerative eco-industry, as well as boosting well-being based on recovered environmental integrity. Based on existing literature, key principles of CE may be summarised as follows:

1. Design for Longevity: Products should be designed to last longer, be easily repaired, and have modular components to facilitate upgrades.
2. Resource Efficiency: Usage of all resources should be conducted more efficiently by reducing consumption and minimizing waste in production processes.
3. Waste as a Resource: Materials that would typically be considered waste are viewed as potential resources for new products, fostering a closed-loop system.
4. Collaboration: Encourages cooperation among businesses, consumers, and governments to create sustainable systems and support each other in the transition.
5. Business Model Innovation: Shifts from ownership to service-based models such as leasing, or incorporating partnership and sharing , or reducing the need for new products

It must be emphasized that the CE cannot be obtained through attempts by individuals. Instead, the CE involves a systemic change in companies, industries, and economies through radical shifts in societal values, norms, and behaviours (Chizaryfard et al., 2020). Furthermore, the CE is intrinsically bound to environmental innovation in the way societies legislate, produce, and consume (Prieto-Sandoval et al., 2018; Suchek et al., 2021).

2. The Impacts of Textiles and Apparel Industry and Adaptation Models on the Circular Economy

The textiles and apparel industry is reported to represent 3.7 per cent of world merchandise exports in 2022 (WTO, 2024). The global apparel market size is expected to reach US$2.6 trillion in 2025, growing by a projected rate of 4%. The production of textiles and apparel is realized through geographically long and complex supply chains. Supply chains in the sector are labour-intensive, with economies specializing in the production and transformation of raw materials into fabrics, fibre, and finished products. This long and diverse chain consists of growers and processors of raw fibres, yarn spinners, weavers, knitters, dyers and finishers, garment makers, product manufacturers, and distributors. The range of textile products is quite varied, from interiors and automotive fit-outs to geo-textiles, Agri-textiles, and hygienic textiles, but the sector is primarily fashion-driven, as most global fibre production (60%) is used for clothing (Niinimäki et al., 2020). The current practices of the textile and apparel industries are widely criticized for environmental problems such as excessive waste generation, intensive use of hazardous chemicals, water, and energy, the release of air pollutants, greenhouse gas (GHG) emissions, and inadequate disposal of used textile products into the municipal solid waste (Ozek, 2023). The industry produces both operational and environmental waste during the life cycle of various products, including fiber, yarn, and fabric production, dyeing and finishing processes, and distribution and transportation operations (Niinimäki et al., 2020; Patti et al., 2021; Schmutz & Som, 2022). According to the Ellen MacArthur Foundation (2017), the GHG emissions from the textile and apparel industry exceed the combined emissions from maritime transport and international aviation. Further, it is expected that this industry will account for a quarter of the world's carbon emissions by 2050 if air pollution and GHG emissions continue along this path (Ellen MacArthur Foundation, 2017). The manufacturing processes of textile products such as garments, footwear, and technical and household textiles consume massive amounts of water and primary raw materials. According to an estimate, this industry consumes 93 billion cubic meters of water annually, discharges 20% of the global industrial wastewater, and 200,000 tons of untreated dyes; hence, it is recognized as the second largest water-polluting industry in the world (Khan et al., 2023; Saha et al., 2021; UNCTAD, 2019). The untreated wastewater discharge from textile companies has adversely affected groundwater purity, which causes a serious threat to human health and animal species (Saha et al., 2021). In addition, microplastics and chemicals are released into the wastewater from household washing of garments (Camilleri, 2020). Further, due to the low recycling rate, post-consumer textile waste is often incinerated, landfilled, or exported to developing economies (Camilleri, 2020).

Figure 2. Global Impacts of Textile and Apparel Industries Based on the Linear Economy Model

The ongoing practices of textile and apparel companies, acting in accordance with the concept of linear economy are liable to induce various impacts on the environment, social life, and economy. The primary impact factors are illustrated in Fig. 2. As shown in the figure, the conduction of textile and apparel production in respect of the current linear economy model results in serious harmful impacts in consideration of climate change, environmental safety, and human health. The long supply chains and high energy demand in manufacturing of textiles, apparel, and footwear industries produce 8–10% of the overall carbon emissions (European Parliament, 2021). Around 1.2 billion tonnes of CO2 equivalent (UNFCCC, 2018) generated by these sectors surpasses total emissions from international aviation and maritime shipping. The European Union is reported to produce 12.6 million tonnes of textile waste per year. Apparel and footwear alone are responsible for 5.2 million tonnes of waste, which is equivalent to 12 kg of waste for each person per year. Currently, only 22% of post-consumer textile waste is collected separately for reuse or recycling, while the remainder is usually incinerated or landfilled.

In general, companies in the textile and apparel industry have focused on the optimisation of a linear clothing economy, which enables an increase in speed, trendiness, and cheapness at the expense of quality and sustainability (Pedersen et al., 2019). This approach is likely to boost even higher clothing production (Ellen MacArthur Foundation, 2017), but also high pressure to reduce the use of natural resources such as water and land, as well as resultant harms on the waste growth, greenhouse gas emissions, and fresh water pollution (EEA, 2019).

Owing to the increasing sustainability issues, environmental regulations for the textiles and apparel industry are becoming more stringent and require manufacturers to implement circular design principles and practices to ensure their engagement in sustainable and closed-loop business models. By adopting such business models, manufacturers can reuse and recycle their resources, effectively handle the chemicals in an environmentally friendly manner, and drive consumers towards sustainable consumption practices (Camilleri, 2020). Among these models and business strategies, the circular economy (CE) is recognized as an emerging paradigm that has changed the definition of waste from materials, products, or substances that cannot be used anymore to a more valuable resource (Schmutz & Som, 2022).

In response to high pressure to move towards CE, the concept of circular economy is widely accepted and therefore attempts have been made to adapt into the manufacturing strategies in overwhelming crucial environmental issues through closed-loop production systems that foster reusing and recycling products, reducing raw material and natural resource consumption, minimizing waste, creating value, and achieving environmental stewardship (Awan et al., 2021; Ul-Durar et al., 2023). The presence of a strong relationship between the principles of CE and the sustainability concept was proved by a study (Colucci & Veccchi, 2020), endorsing the opinion that there is a beneficial interrelation between the two. The study exhibits the emergence of categories of CE-related practices as well as challenges for the CE adoptation. Some insights on the nature of these challenges hindering the CE implementation and also by what method they can be turned into sources of competitive leverage are demonstrated.

Figure 3. Individual Stages of a CE Model for Adaptation into Textiles and Apparel Industry (Furferi et al, 2022).

Possible directions for new ways and solutions to convert processed textiles into inputs or byproducts for re-

manufacturing are referred to as a trump card for the future of the textile sector by an article about CE guidelines for the textile industry (Furferi et al, 2022). This study aims to provide a set of guidelines to lead textile industries in the transition from conventional production operations to a systematic approach in conjunction with the CE. The steps of operations proposed by the relevant method are applicable to products based on the use of regenerated materials or the combination of reused wool products certified as organic materials. This method was claimed to be capable of recovering a material "better than the virgin

one" with important aesthetic characteristics and greater durability in terms of the product. The individual phases of the circular process developed by this particular approach are given in Fig. 3. In consideration of such a framework, the following challenges are explained to be confronted with reference to a company in Italy.

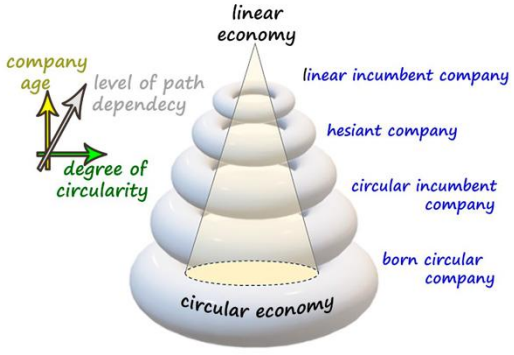
- Definition and drafting of a Sustainability Report;
- Optimization of the (raw and recycled) materials was conferred.
- Eco-Design of textile products, so that they are as environmentally friendly as possible; Implementation of a supply chain traceability, integrating the Blockchain paradigm;
- Assessment of products and processes in terms of Life Cycle;
- Optimization of the textile products distribution;
- Improvement of the consumption practice by end-users and study of products' end of life; Reintroduce most products in the circular process.

There exist some studies in the literature proposing a roadmap or guidance for transmission. Such a transmission operation requires firm changes in the company logic they are creating, delivering, and capturing value, including changes in markets, business logic, and organisational culture (Lewandowski, 2019). One study proposed a roadmap to transform the current business model into a circular one (Frishammar & Parida, 2019). A theoretical framework of circular economy ecosystem emergence was presented in a study (De Vito, 2025), as a transitional phase or "real utopia". Potential drivers behind emergence were defined by uncovering the pivotal role ecosystem orchestrators play in governing the interdependencies between actors and activities across the different intersecting ecosystems. The study concluded that the power and efficiency of orchestration can play a very critical role in the transformation. However, in most studies, the nature and capabilities of the company relevant to the shift are not taken into consideration.

The companies are willing to develop capabilities for anticipating opportunities and quiting the perceived linear business culture, and also reorganizing all the resources of the company, accordingly. The point and grounds of the company within the global value chain affect the style companies can impelement the basics of circularity. A strong position that allows control over the circularity of the value chain can be achieved through ownership or by allying in business ecosystems. The three factors affecting the transition to the CE model are illustrated in Fig. 4. The stages of progress between the linear and circular economy model are redefined as linear incumbent, hesitant, circular incumbent, and born circular company. This study aimed to identify factors that affect the business model transformation process of incumbent textile companies and capabilities needed to overcome the inertia caused by these factors. It appears that dependency on the prevailing product portfolio, a product-oriented business model, and the position in the supply chain crucially affect the efficiency with which incumbent companies can become circular. Dependency on the prevailing product portfolio may serve the purpose of economic performance, but not necessarily ecological and sustainable performance.

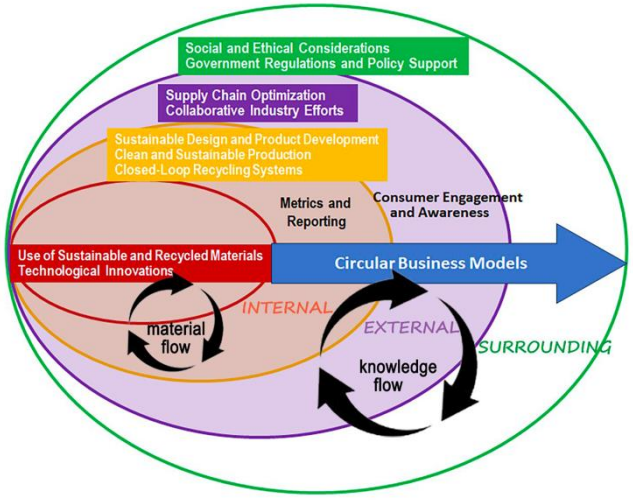
Figure 4. The Transmission Path of Textile and Apparel Companies from Linear to Circular Economy (adapted from Salmi and Kaipia, 2022)

Another study (Herrador & Imanisihi, 2025) investigated the dynamic field of the circular textiles and fashion industry of Japan, featuring its distinctive position and potential to catalyse business competition and collaboration with the European Union. It was based on desk research with a systematic literature search, and directed twenty interviews with partners from SMEs to large multinationals, government officials, clusters, and public and private sector stakeholders in Japan and the EU. The analysis of the



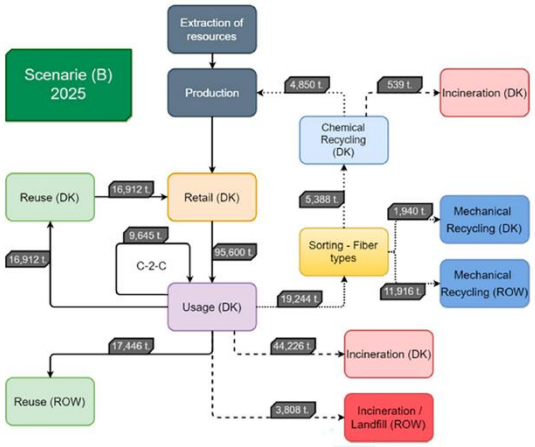
circular textile and fashion industry of Japan pointed out the private company activities promoting circularity among local enterprises and consumer trends. The challenges in the transition operation were given as the lethargic circular textile and fashion commerce between demographic and economic trends, the collapse of traditional textile enterprises, and the domination of multinationals. The difficulty for manufacturing businesses is to become "self-sufficient" regarding product development and sales because they are concentrated in specific manufacturing fields, and in most cases, they rely on outsourced production rather than creating their own goods. The strengths and challenges of companies in the supply chain are tabulated with respect to company style in Table 1. -Table 1 is in the Annex.- Trading companies appear to conduct circularity better than others. A synergic cooperation was designed between EU and Japanese circular textiles and fashion businesses to promote circularity in both regions, address challenges, and seize opportunities. This article may provide helpful insights for policymakers and businesses, ranging from local startups to global enterprises, aiming to capitalize on Japan's CTF. Industry In the adaptation of CE, the existence of circular economy policies and planning approaches in cities is often remarked as a critical supporting factor and an emerging research field. A recent article

(Christensen, 2021) examined how municipalities and constituent of city facilitate and support the adaptation of CE through multiple modes of governance, e.g., by means of their own assets. To keep the ownership of utility and waste



companies for supporting the CE; the assignment of rule enforcement or economic regulation, or through facilitating, coordinating, collaborating, and encouraging, is analysed in depth with reference to Denmark. It was stated that the Danish municipalities collaborated with local stakeholders to close the material loop for demolition materials and textile waste. The potential of increasing textile recycling in Denmark is analysed by a set of scenarios developed on a baseline projection and variations with increasing the amount of textiles recycled by mechanical and chemical processes. The first scenario was developed on the basis of an assumption that the current NGO-based system will be maintained, while a second scenario was designed to underline the potential of a new system whereby all textiles are collected under a municipal system and recycled in Denmark. A collection scheme was established to map and assess the quantity and quality of textile waste. The local municipality implemented a scheme for the use of clothing and shoes. Two different collection systems were used due to the lifestyle differences between the two socio-economic classes. It was seen that the collection rates for source-separated municipal solid waste are higher in one-family homes than in high-rise homes. The outline of the second scenario is given in Fig. 5, where the flow of materials is schematically shown with potential reuse and recycling steps. The ratios of reused and recycled materials are increased as much as 30-40%. It may seem that more than half of the 95.600 tonnes of textiles sold in Denmark are achieved to be reused or recycled within Denmark and other countries (ROW). The scepticism about the actual fate of the exported textiles and partly disposal details (landfilled, incinerated, or recycled) is pointed out as a drawback of this scenario. The revision on the second scenario assumes that it would be easier for municipalities to verify that the collected textiles are actually recycled and that the system will create a closed loop where textile fibres are continuously recycled and not landfilled after being reused once. The conclusion of this study has confirmed that municipalities can function as an important change agent to support and facilitate the transformation to CE.

Figure 5. Baseline Textile Flow for a Scenario B: 2025 (modified for CE approach) in Denmark. (Christensen, 2021)



A study by Salmi and Kampia (2022) investigated the capabilities that enable clothing brands to transition from a linear economy to Circular Business Models. The study found that the company-level implementation of the circular economy is still poorly understood, leaving companies without clear guidelines on how to make the transition. The study focused on two key issues: how past trajectories influence the ability of clothing brands to adopt circular business models, and the specific capabilities needed to overcome transformation-related challenges. The research, conducted in seven fashion brand companies in Finland, revealed that a company's product orientation and its reliance on the current product portfolio significantly influence its ability to transform its business model.

3. The Proposed Method for Adaptation of Circular Economy Into Textiles and Apparel Industry

An assignement for implementing the selected CE model in the textiles and apparel industry should be conducted by a systematic approach that integrates sustainable practices throughout the full supply chain, from raw material sourcing to production, consumption, and end-of-life management. The prime main objectives are to minimize waste and to extend product life cycles by creating closed-loop systems where materials are continuously reused and recycled. These principles require systematic operations at both the inside and outside the company level. The internal tier involves the raw material supply, design, and production. The external tier extends until the customer purchases, uses, and disposes of it at the end of life. The surrounding tier consists of the actions of policy makers and the collaboration of local administration and municipalities. This model is illustrated in Fig.6.

Figure 6. The Extent and Tasks of Three Tiers of CE Model for Textiles and Apparel Industry (borderlines of internal,

external, and surrounding tiers)

Integration of these three tiers and the flow of material and knowledge between them are obviously critical in terms of circularity, collaboration, and transparency. The completion of each task in accordance with the conditions and requirements of the company and also in comply with regulations is critical steps for the adaption of circular economy model. The essential tasks are reviewed below in relevance to tiers.

The Internal Tier (Level)

I. Use of Sustainable and Recycled Materials

- Organic and Renewable Materials: Using organic cotton, hemp, or bamboo can reduce environmental impacts, as these materials typically use less water and chemicals compared to conventional materials. Fiber supply from Better Cotton Initiative (BCI) or Responsible Wool campaigns and promoting ecological farming are also important. In the procurement of raw materials, internationally recognized standards, such as GOTS (Global Organic Textile Standard), OCS (Organic Content Standard), and GRS (Global Recycled Standard), may also be among the selection criteria.
- Recycled Fibers: Using fibres made from recycled materials, such as recycled polyester (from plastic bottles) or regenerated cellulose fibres (from textile waste), can reduce the need for virgin materials.
- Biodegradable Textiles: The Development and use of biodegradable fibres, which break down naturally at the end of their life, are crucial for reducing textile waste in landfills.

II. Technological Innovations

- Blockchain for Traceability: Implementing blockchain technology can ensure full transparency of materials, production processes, and product lifecycles. This can help brands track the origins of fibres, ensure ethical practices, and facilitate recycling.
- Digital Tools for Waste Reduction: Advanced technologies like 3D printing, AI-driven demand forecasting, and virtual fitting rooms can reduce waste in production and improve inventory management.

III. Sustainable Design and Product Development

- Design for Durability: Clothes should be designed to last longer, be repairable, and resist trends that encourage short-term use. This includes using durable materials, strong stitching, and modular designs.
- Design for Recycling: Products should be made from materials that can easily be disassembled and recycled. For example, avoiding mixed materials (like cotton and polyester blends) that are hard to recycle.
- Cradle-to-Cradle Design: This design philosophy focuses on creating products that can either be reused or safely returned to the environment, with materials cycling through biological or technical loops.

IV. Closed-Loop Recycling Systems

- Textile Collection and Sorting: Implement systems for collecting used clothing, either through brand take-back programs, third-party collectors, or municipal initiatives. Collected garments can then be sorted for reuse or recycling.
- Mechanical and Chemical Recycling: Establish recycling technologies to break down textiles into their raw components. Mechanical recycling is useful for cotton and wool, while chemical recycling can be applied to synthetics like polyester.
- Fiber-to-Fiber Recycling: Developing technologies that can turn post-consumer textiles back into high-quality fibres suitable for new garments is key for a closed-loop system, both biological and technical loops.

V. Clean and Sustainable Production

- Cleaner Production: Clean textile production conceptually leads to an integration of continuous applications of preventive environmental strategies to processes, products, and services, aiming to minimize possible risks to people and the environment, as well as to increase material efficiency. The utilization of clean production or Best Available Techniques (BAT) practices contributes to the preservation of raw materials and energy sources, reducing or eliminating toxic materials and minimizing the quantity and toxicity of the emissions and the residues during the production processes.
- Sustainable Production Technics: Plasma technology, ozone fading, enzymatic processing, and super whitewashing are the approaches to make textile wet processing more environmentally friendly. To conserve the world's resources while keeping up with surging consumer demands, necessitates the exercises of sustainable practices and processes.
- Implementation of the Green Production Concept: It is known that swings in fashion trends and the shortening of vogue cycles are major accelerators for the disruption of ecological balance. A profusion of pioneering initiatives and advancements to achieve certain sustainable remedies within the production and consumption paradigms of the contemporary clothing sector is critical. Moreover, sustainable techniques within the apparel sector encompass not just environmentally friendly supply chain control, but also the facilitation of a cost-effective and socially agreeable production setup.

VI. Circular Business Models

- Search for CE Business Models: A circular business model is a powerful tool that articulates how an organization can create, deliver, and capture value for its stakeholders while minimizing ecological and social costs. By adhering to the circular economy's principles of Designing out waste and pollution, Keeping products and materials in use, and Regenerating natural systems, these models have the potential to significantly reduce waste and inspire a more sustainable future.
- Green Deal Concept: A business model complying with the conditions of European Green Deal which was officially launched in 2019 is essential. A new phase of ambitious environmental action and sustainable development within the EU has evolved into a comprehensive policy framework with various initiatives and legislative proposals (Lüttin, 2025) aimed at achieving its sustainable green production and consumption objectives.
- Resale and Second-Hand Markets: Brands can set up platforms to sell pre-owned clothes or partner with second-hand marketplaces to extend the life of garments.
- Rental and Leasing Models: Instead of ownership, consumers can rent clothing for specific occasions (e.g., formal wear, maternity wear), helping to reduce overconsumption and waste.
- Repair and Refurbishment Services: Providing repair services or offering incentives for customers to repair damaged garments can extend product lifecycles. Brands can also refurbish and resell slightly used or damaged items.
- Cleaner Production: Clean textile production conceptually leads to an integration of continuous applications of preventive environmental strategies to processes, products, and services, aiming to minimize possible risks to people and the environment, as well as to increase material efficiency. The utilization of clean production or Best Available Techniques (BAT) practices contributes to the preservation of raw materials and energy sources, enabling the reduction or elimination of toxic materials and minimizing the quantity and the toxicity of the emissions and the residues during the production processes.
- Sustainable Production Technics: Plasma technology, ozone fading, enzymatic processing, and super whitewashing are the approaches to make textile wet processing more environmentally friendly. To conserve the world's resources while keeping up with surging consumer demands, necessitates the exercises of sustainable practices and processes.
- Implementation of the Green Production Concept: It is known that swings in fashion trends and the shortening of vogue cycles are major accelerators for the disruption of ecological balance. A profusion of pioneering
- Initiatives and advancements to achieve certain sustainable remedies within the production and consumption paradigms of the contemporary clothing sector is critical. Moreover, sustainable techniques within the apparel sector encompass not just environmentally friendly supply chain control, but also the facilitation of a cost-effective and socially agreeable production setup.

VII. Circular Business Models

- Search for CE Business Models: In general, a circular business model is expected to articulate the logic of how an organization creates, delivers, and captures value to its broader range of stakeholders while minimizing ecological and social costs. An appropriate model adhering to the circular economy's three fundamental principles, namely Design out waste and pollution; Keep products and materials in use; and Regenerate natural systems, should be selected and implemented.
- Green Deal Concept: A business model complying with the conditions of European Green Deal which was officially launched in 2019 is essential. A new phase of ambitious environmental action and sustainable development within the EU has evolved into a comprehensive policy framework with various initiatives and legislative proposals (Lüttin, 2025) aimed at achieving its sustainable green production and consumption objectives.
- Resale and Second-Hand Markets: Brands can set up platforms to sell pre-owned clothes or partner with second-hand marketplaces to extend the life of garments.
- Rental and Leasing Models: Instead of ownership, consumers can rent clothing for specific occasions (e.g., formal wear, maternity wear), helping to reduce overconsumption and waste.
- Repair and Refurbishment Services: Providing repair services or offering incentives for customers to repair damaged garments can extend product lifecycles. Brands can also refurbish and resell slightly used or damaged items.

The External Tier (Level)

VIII. Metrics and Reporting

- Circularity Metrics: Brands need to track and report on key circularity indicators, such as the percentage of recycled materials used, the amount of waste diverted from landfills, and the lifecycle extension of garments.
- Life Cycle Assessment (LCA): Conducting LCAs for products can help companies identify the environmental impacts of their operations and make improvements in areas like water usage, carbon footprint, and waste generation.

IX. Supply Chain Optimization

- Efficient Use of Resources: Optimize the supply chain to reduce resource use, including water, energy, and chemicals. Technologies like digital printing and waterless dyeing can minimize environmental impact.
- On-Demand Production: Shifting towards on-demand or small-batch production reduces overproduction and unsold inventory, which often leads to waste.
- Local Production and Shorter Supply Chains: Localizing production can reduce transportation emissions and support more agile and responsive manufacturing systems.

X. Consumer Engagement and Awareness

- Promote Conscious Consumption: Brands can educate consumers on the environmental impact of fast fashion and encourage them to buy less but better-quality, durable products.
- Transparency and Labelling: Providing clear information on the origin of materials, recyclability, and care instructions can help consumers make informed decisions and prolong the life of their clothes.
- Incentivizing Sustainable Choices: Offering discounts or loyalty rewards for returning used garments, renting instead of buying, or choosing sustainably-made products can motivate consumer participation in circular systems.

XI. Collaborative Industry Efforts

- Shared Infrastructure: Collaborating with other brands, suppliers, and even competitors to share recycling facilities, repair centres, and logistics can reduce costs and improve the scalability of circular solutions.
- Industry Standards and Certifications: Adopt and develop industry-wide standards for sustainable and circular practices, such as certifications for recycled materials, fair labour practices, and eco-friendly production methods.

The Surrounding Tier (Level)

XII. GGF Government and Policy Support

- Extended Producer Responsibility (EPR): Governments can mandate that brands take responsibility for their products throughout the entire lifecycle, including take-back schemes and recycling.
- Incentives for Sustainable Practices: Financial incentives, such as tax reductions for companies using recycled materials or penalties for excessive waste, can encourage more circular practices.
- Regulations on Waste and Pollution: Introducing strict regulations to limit textile waste, reduce emissions, and ensure proper disposal of hazardous chemicals can drive the transition towards circular practices.

XIII. Social and Ethical Considerations

- Fair Labor and Ethical Production: Circular models must also ensure fair wages, safe working conditions, and respect for workers' rights throughout the supply chain.
- Inclusivity in Circular Systems: Engaging with local communities, small businesses, and marginalized groups can create inclusive circular solutions that benefit everyone, not just large corporations.

4. Outcomes Of the Adaptation of the Circular Economy

The transition to a circular economy in the textile and apparel industry offers several potential outcomes, which can positively impact the environment, economy, and society. The important outcomes of such progression may be divided into two groups: corporational benefits and collective benefits. Potential benefits and earnings at the company, economic, and social levels are critical to maintaining the circular economy model.

Corporational Benefits

Resource Efficiency: Conservation of Raw Materials and Closed-Loop Systems

Circular practices focus on recycling fibres and reusing materials, reducing the need for virgin resources like cotton, polyester, and water. Fibers can be recycled into new products, creating a closed-loop supply chain where waste is minimized, and materials are continuously reused.

Reduction in Waste and Pollution: Extended Product Life Cycle and Minimized Pollution

Circular economy promotes designing for durability, repair, and reuse, significantly reducing the volume of textile waste that ends up in landfills. By recycling materials and reducing the need for virgin fibres, emissions from textile production (such as water pollution and CO2 emissions) can be minimized. This leads to a cleaner, more sustainable supply chain. Lower waste generation reduces environmental pollution, including microplastics in oceans and chemicals released from synthetic fibres.

Improved Supply Chain Transparency: Traceability and Accountability

The circular economy requires transparent supply chains to track the flow of materials, increasing consumer awareness of product sourcing and production processes. This can also build trust between brands and consumers.

Cost Savings for Businesses: Reduced Production Costs and Lower Waste Disposal Costs

By using recycled or reclaimed materials, businesses can lower material costs in the long term, leading to more efficient production cycles. On the other hand, companies can also save on waste management expenses by designing products that are easier to disassemble, reuse, or recycle.

Improved Brand Reputation: Sustainability Leadership and Customer Engagement

Brands that embrace circular practices are seen as leaders in sustainability, which can attract environmentally-conscious consumers and enhance brand loyalty. It is also believed that the circular model encouragea customers to participate in take-back programs, resale platforms, and repair services, fostering stronger connections between brands and their audience.

Economic Growth and New Business Models: Resale and Rental Markets, Innovation in Materials, and Job Creation

The rise of second-hand clothing, rental services, and clothing swaps can become more mainstream, creating new business opportunities and revenue streams. The development of sustainable textiles (e.g., biodegradable fabrics, textiles from recycled waste) may lead to new material innovations, sparking economic growth and attracting investment. Additionally, new job opportunities could emerge in areas like textile recycling, repair services, and circular business design.

Consumer Behaviour Shift: Ethical Consumerism and Increased Demand for Durable Products

The adoption of circular models encourages consumers to move towards more conscious consumption habits, valuing quality and sustainability over fast fashion trends. With more awareness of environmental impacts, consumers may prefer longer-lasting products, which can reduce the overall volume of clothing consumed.

Environmental and Social Benefits: Decreased Carbon Footprint and Social Impact

Circular production models can significantly reduce the carbon footprint of the textile industry, as recycling fibres requires less energy than producing new materials. By promoting fair labour practices and ensuring that clothes are designed for reuse or recycling, circular models can improve working conditions and support ethical manufacturing practices.

Regulatory and Policy Impacts: Government Incentives and Policy Changes

Governments may introduce incentives or regulations that promote circular business models, such as tax breaks for recycling or penalties for waste. This could further accelerate the adoption of circular practices across the industry. Various means of government supports and incentives for supporting circular practices may also be introduced through legislation, like extended producer responsibility (EPR) policies, tax incentives, and subsidies for sustainable businesses.

Global Collaboration and Standardization: Harmonized Standards and Standardization and Transparency

The shift to a circular economy may encourage the creation of global standards for textile recycling, reuse, and eco-labelling, enabling brands to collaborate across borders on sustainability goals. Global regulations and standards for recycling, eco-labelling, and sustainability practices can improve transparency, benefiting both consumers and businesses.

Global Sustainability Goals : Contribution to SDGs

The circular economy can help the textile and apparel industry align with global sustainability goals, such as responsible consumption and production (SDG 12), climate action (SDG 13), and decent work (SDG 8).

5. Conclusion

This study is hoped to make some theoretical contributions to the understanding of CE practices in the textile and apparel industry and their relevance to sustainability. The basics of CE and possible benefits and challenges of adapting a CE business model are discussed, and a framework for CE model adaptation into the textile and apparel industry is proposed. There appears to be a significant positive correlation between sustainability practices and the adoption of CE strategies in the textile and apparel industry. Therefore, the application of circular economy in the textile and apparel industry is expected to lead to more sustainable production processes, reduced environmental impact, and a shift towards ethical and responsible consumerism by means of new business models. A circular economy in the textile and apparel industry is very likely to generate transformative outcomes. However, this transformation requires systemic changes, collective efforts, and collaborations of producers, retailers, particularly brand holders, consumers, and policymakers. Changing the focus of business to CE is vulnerable to facing various obstacles such as managerial reluctance and limited customer and governmental support, as well as barriers to obtaining the appropriate technologies (Saha et al., 2021). Meanwhile, the demand and market for new circular products have still been developed (Lüdeke-Freund et al., 2019; Lewandowski, 2016) since the last decade.

It is clear that such a transition from traditional production schemes to a systematic circular economy is not an easy and individual operation. Every step of the transition will require a strong commitment from the company towards its stakeholders and the implementation of several procedures, often accompanied by a certification from third parties. It also requires a mutual partnership between stakeholders to contribute to common problems throughout the flow of material and knowledge. In regard to the proposed methodology, the conduction of required tasks at the internal level may be handled relatively easily compared with other tiers. The pace and success of internal operations should depend on the degree of circularity of the company. It is expected to be rather easier in the cases of young and circularity-focused companies. On the other hand, the external and surrounding tiers are more challenging and cumbersome. Coordinating and unifying all partner companies and eliminating their traditional characteristics

and old habits. In this sense, product-orientation, the existing product portfolio, and the position in the supply chain are very likely to build up significant inertia and resistance to transforming the business model.

The awareness and attitudes of consumers, as well as the collaboration and participation of NGOs and municipalities in the reusing and collecting textile materials and products, are also among the critical success factors of this transition. It is also known that several regulations and initiatives globally aim to promote the circular economy in the textile industry at local, national, and international levels. The United Nations Environment Programme (UNEP) is initiating resolutions to provide strategic leadership and promote cooperation across sectors to expedite a fair transition towards a sustainable and circular textile value chain. The policymakers and local authorities are also expected to facilitate this transition period by preparing persuasive, mandatory, and fair regulations. Hopefully, these findings and beneficial insights will enable practitioners and policymakers to accelerate circular economy transformation.

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TABLE 1.

Table 1. Companies in each supply chain, in their strengths and challenges (Herrador & Imanishi, 2025).

Supply Chain	Enterprise type	Strengths	Challenges
Upstream (synthetic textile manufacturing and spinning industry)	Mainly large companies (e.g., Toray, Teijin, Toyobo).	Technological development capabilities (e.g., development and expansion of carbon fibre and new materials and applications, development of materials derived from non-fossil raw materials)	Diversified and textile businesses' revenue streams are non-clothing
Middle stream (dyeing and processing industry, textile industry)	Focus on small and medium-sized enterprises, textile production areas throughout Japan	Processing technology coordination (with material manufacturers and other process companies), cooperation with different fields (e.g., with the automotive and electronics industries), and technology transfer (human resources development)	Expansion and independence in non-clothing (own product development and sales)
Downstream (sewing, manufacturing, apparel)	SMEs	Ability to disseminate fashion information (brand power)	Increasing global competitiveness, responding to human rights issues, and ecology.
Other (trading companies, SPAs)	Mainly large companies (e.g., Itochu, Uniqlo)	Ability to disseminate fashion information (brand power, internat. expansion), grade of responsiveness to environmental protection and consumer safety (recycling, false labeling, measures against hazardous substances).	Increasing global competitiveness, responding to human rights issues, and ecology.