STITCHING SUSTAINABILITY

THREADS AS CATALYST OF CHANGE IN FASHION

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Abstract

In the ever-evolving fashion landscape, sewing threads—traditionally seen as minor garment components—are emerging as powerful catalyst of change, empowering designers to integrate sustainability into their creative processes. This paper explores the transformative role of disassembly-enabling materials in fostering sustainability within the apparel industry, focusing on a groundbreaking case study in textile innovation.
By examining how heat-dissolvable sewing threads and thermal disassembly systems facilitate efficient garment recycling, this study highlights their potential to drive a paradigm shift in fashion design. A single case study methodology is applied to investigate an innovative approach that integrates advanced materials, automated disassembly, and circular economy principles to enhance environmental performance while preserving aesthetic and functional integrity.
Through this lens, the authors illustrate how threads can transcend their conventional role, becoming key enablers of fiber-to-fiber recycling and waste reduction. This exploration underscores the importance of viewing garment construction not just as a manufacturing process but as a strategic intervention for sustainability. By embedding Design-for-Disassembly (DfD) and Active Disassembly principles into production methods, this research challenges designers to rethink material choices—positioning threads as dynamic catalysts shaping fashion's transition toward circularity.

Keywords: *Threading Sustainability, Sustainable Innovation, Circular Fashion, Design for Disassembly, Active Disassembly.*

INTRODUCTION

The fashion industry embodies a paradoxical role as a powerful cultural influencer and a significant driver of socio-environmental degradation. While the industry exerts considerable influence on social and cultural dynamics, it simultaneously has profound adverse effects on environmental health and the depletion of finite resources, mainly due to its perpetuation of a consumerist economic model characterized by mass production (Jardim, 2023). Reports from the European Union (2022) and the Hot or Cool Agency (Coscieme et al., 2022) elucidate these adverse impacts, highlighting the invasive processes inherent to the industry. Several scholars further articulate how the industry's practices restrict fashion experiences and sustain unsustainable production patterns globally (Bertola & Colombi, 2024; D'Itria & Aus, 2023; Coscieme, Manshoven, et al., 2022; Niinimäki et al., 2020; Fletcher, 2018).

The environmental impacts of the fashion industry are both profound and pervasive, marking it as one of the most resource-intensive sectors globally. A significant contributor to global environmental degradation, the fashion industry is responsible for approximately 10% of global carbon emissions (European Parliament, 2020). This significant carbon footprint results from the entire lifecycle of garments—from raw material extraction, including the energy-intensive processes of producing synthetic and organic fibers and dyes, to the transportation and retail phases (Niinimäki

et al., 2020). The reliance on fossil fuels for energy and the emission of greenhouse gasses throughout production processes exacerbate the industry's impact on climate change (Coscieme et al., 2022). Textile waste further compounds the sector's environmental footprint. The fashion industry generates an estimated 40 million tons of textile waste annually, a significant portion of which is disposed of in landfills or incinerated (Kent, 2024). This waste occupies valuable landfill space and contributes to greenhouse gas emissions through methane release from decomposing textiles and CO2 emissions from incineration (Gupta et al., 2022).

Water consumption is another critical issue (Bailey et al., 2022). The fashion sector is one of the largest consumers of freshwater, utilizing vast amounts for dyeing and finishing processes. For instance, it is estimated that producing a single cotton T-shirt requires around 2,700 liters of water, equivalent to one person drinking over two and a half years (Muthu, 2018). This pollution, laden with harmful chemicals and dyes, disrupts the natural balance, leading to severe environmental and health repercussions (Rana, 2024). The discharge of untreated wastewater from textile manufacturing facilities contaminates rivers and lakes, adversely affecting aquatic ecosystems and local communities and impacting the social aspect of workers' health and community safety (D'Itria, 2023). Furthermore, the fashion industry faces other significant social issues deeply intertwined with its global supply chain. Workers, particularly in developing countries, often endure poor working conditions, low wages, and exploitation due to rapid production cycles that demand cost-cutting at the expense of worker welfare (Neiveling, 2024; Seidu et al., 2024).

According to the aforementioned, the pervasive and severe social and environmental exploitation within the fashion industry establishes it as a significant global concern for environmental and social justice (Parvin et al., 2020). The sector challenges are predominantly a consequence of the linear development model that dominates the fashion sector (Dissanayake & Weerasinghe, 2021). This model, a remnant of the first industrial revolution, adheres to a cradle-to-grave paradigm that depletes natural resources and discards them without considering their potential for regeneration or reuse (Braungart & McDonough, 2009). It fosters overproduction, encourages compulsive consumerism, and leads to the early disposal of garments due to their physical and semiotic obsolescence. Consequently, this system drives irresponsible practices such as excessive consumption and premature disposal of fashion products.

Given these challenges, it is essential to reevaluate traditional linear development models and adopt sustainable frameworks such as the circular economy. The European Commission increasingly recognizes this model as the leading paradigm for separating sustainable fashion innovation from resource exploitation (EUR-LEX - 52020DC0098 - EN - EUR-LEX.) (n.d.). https://eur-lex.europa.eu/legal-content/EN/ section, bolstered by the direct testimony of one of the authors who serves as the Chief Technology Officer of the analyzed company and provides unique insights, underscores how yarns enable designers to reevaluate their practices through sustainable innovation. Section 4 concludes the article by exploring how the presented case study lays the groundwork for future research. It considers how design can be leveraged to formulate new strategies for fostering sustainable innovation in the fashion industry.

METHODOLOGY

This study employs a single-case study methodology to examine the transformative potential of advanced technologies in promoting sustainability within the fashion industry. This approach suits this research because it provides in-depth and contextually rich insights into complex phenomena (Yin, 1994). Single-case studies are a valuable research methodology for conducting thorough and holistic examinations. Focusing on a single case allows for exploring detailed aspects of the subject that might be overlooked in broader studies (Levy, 1988). Single-case studies are distinguished from multiple-case studies by their focus on one particular instance rather than replicating across several cases. The author acknowledges that although this approach necessitates careful consideration of validity and reliability, single-case studies offer several distinct advantages for this study compared to multiple-case studies. Indeed, this streamlined approach is particularly advantageous for developing high-quality theories, as single-case studies often produce more affluent and nuanced theoretical insights. The depth of analysis afforded by single-case studies allows this

study to profoundly understand the subject under investigation. This methodology provides detailed descriptions of phenomena and is particularly useful when focusing on specific individuals or small groups (Gustafsson, 2017).
The chosen case involves a pioneering textile company – Resortecs ® - that has integrated cutting-edge materials and manufacturing processes to enhance environmental performance while maintaining high aesthetic and functional standards in garment production.
Data was collected through multiple methods to ensure a comprehensive case understanding. Initially, the authors gathered secondary data from various sources, such as interviews, scientific articles, sector-specific magazines, and industry and government reports (SECRID, 2024; Ozsevim, 2023; Serafin, 2023; EMF, 2021; Pourhashemi, 2021). This process allowed for the case study framework to be built, and the analysis was conducted using thematic coding to identify key patterns and themes related to using innovative technology in sustainable fashion design. These themes were then examined within the broader theoretical framework of the circular economy, as proposed by the Ellen MacArthur Foundation's Vision of a Circular Economy for Fashion (2022). This phase highlights how integrating these yarns can facilitate closed-loop production systems within the design for disassembly paradigm. Specifically, this analysis identified a clear pathway: Fashion products are designed, engineered, and produced to be easily disassembled, enabling them to be reused, remade, recycled, and, when appropriate and after maximum utilization, safely disposed of/composted (Fig. 1) thanks to active disassembly technologies. The disassembly occurs automatically without manual intervention. From this phase, the study also examined the challenges and opportunities faced by fashion companies in implementing circular practices, particularly emphasizing the critical role of material recycling and the lack of adequate recycling enablers. A primary barrier identified in the literature is the insufficient awareness and education regarding circularity within companies and among their workforce (Dissanayake & Weerasinghe, 2022). This lack of knowledge contributes to the limited economic understanding of recycled textiles, as businesses remain uncertain about their market potential and the long-term benefits, thus hindering the full adoption of circular models (Leal Filho et al., 2019). Another major obstacle is the underdevelopment of technologies for material and disassembly, which forces the industry to rely on labor-intensive and costly manual processes (Sandwick, 2019). The absence of advanced textile-to-textile recycling technologies further complicates efforts to establish circular systems. Modern textiles are made from diverse materials, colors, and finishes, and scaling up recycling processes—whether chemical or mechanical—presents both technical and economic challenges (Pedersen, Earley, & Andersen, 2019). Additionally, the inefficient systems for collecting and sorting materials at the end-of-life stage add complexity to the recycling process, preventing the effective implementation of circular practices (Dissanayake & Weerasinghe, 2022). In response to these challenges, the case study suggests potential solutions to overcome these barriers. The company seeks to contribute to a more sustainable future for the fashion and textile industry by advancing innovative recycling practices and developing the necessary technology and infrastructure.
In a further refinement phase, first-hand data was provided by the valuable insights of one of the two authors, who serves as the company's Chief Technology Officer and is directly involved in the transformations described.
Collecting and integrating first-hand data was crucial for obtaining a nuanced and in-depth understanding of the subject. First-hand data, provided directly by one of the authors, provided rich, contextualized insights that secondary data alone cannot offer. This type of data enabled the authors to capture the complexities and subtleties of real-world practices, often revealing underlying dynamics and processes that are not readily apparent in external reports or literature.
The subsequent section presents the case study, emphasizing the role of yarns as the industry's connective threads. These yarns act as powered by active disassembly, guiding the designer and enabling novel scenarios for creating and destroying fashion goods.

RESULTS AND DISCUSSION

The fashion industry has a major environmental impact, generating large amounts of waste, pollution, and carbon emissions. Most garments are made using a linear production model, where clothes are designed, produced, worn, and then discarded—often ending up in landfills or

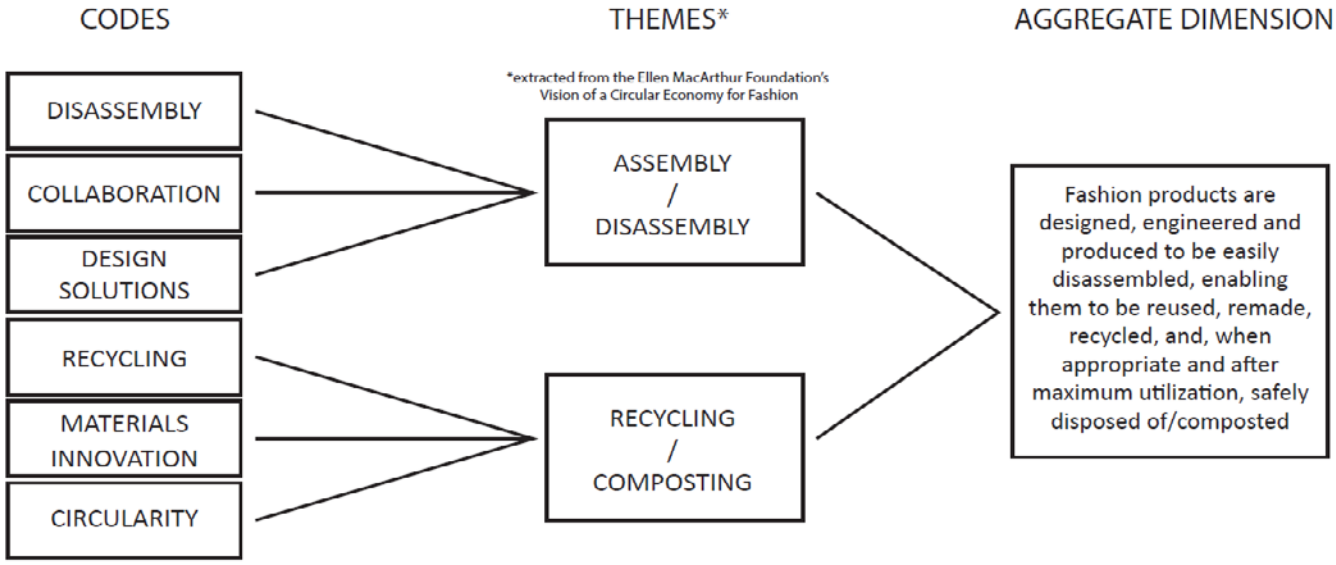

Fig. 01

incinerators. This system wastes valuable materials and contributes to resource depletion and climate change.

One of the biggest challenges in textile recycling is the complexity of garment disassembly. More than 75% of clothes are made with different materials, stitching threads, zippers, and trims, making it difficult to separate and recycle or pre-processing fibers efficiently. Existing recycling methods struggle to process these mixed-material garments, limiting the potential for fiber-to-fiber recycling. New solutions are needed to make garment recycling easier and more effective.

This research focuses on the case study of Resortecs, a Belgian start-up pioneering a novel approach to garment disassembly. Founded in 2017 by Cédric Vanhoeck and Vanessa Counaert, Resortecs developed Smart Stitch™, a patented heat-dissolvable sewing thread, and Smart Disassembly™, the world's first thermal disassembly system. These technologies enable garments to be easily disassembled at controlled temperatures, allowing for the removal of non-recyclable disruptors and improving the efficiency of textile recycling. Resortecs' approach aligns with circular economy principles, offering a scalable and industrially viable solution to one of the most pressing sustainability challenges in fashion.

By analyzing Resortecs' technology and its potential impact on the industry, this study provides critical insights into the integration of active disassembly solutions, their feasibility for large-scale adoption, and their role in shaping a more circular textile ecosystem.

The integration of Design-for-Disassembly (DfD) and Active Disassembly principles into garment production is fundamental to enabling circularity in the fashion industry, as they redefine how textiles are designed, used, and ultimately recycled. Historically, garments have been manufactured with durability and aesthetics as primary considerations, while End-Of-Life (EOL) recyclability was largely overlooked. This has led to a widespread reliance on multi-material compositions and complex constructions, which, while beneficial for performance and design, create significant barriers for recycling.

Design-for-Disassembly (DfD) is an approach that ensures products are intentionally engineered for easy and efficient disassembly at their EOL. This principle is widely used in industries such as electronics and automotive manufacturing, where components must be systematically separated for repair, reuse, or recycling. In textiles, applying DfD means that garments must be designed with future recyclability in mind, ensuring that materials can be efficiently recovered without excessive labor, cost, or contamination.

Active Disassembly, on the other hand, refers to a more advanced approach where disassembly is triggered by an external stimulus, such as heat, vibration, or chemical activation, to facilitate the automated removal of components. Unlike conventional mechanical or manual disassembly processes, Active Disassembly reduces the need for manual intervention, significantly improving

processing efficiency and material purity. Resortecs' Smart Stitch™ technology is a prime example of Active Disassembly applied to textiles.

By embedding heat-dissolvable sewing threads into garment construction, Resortecs enables garments to be dismantled at controlled temperatures (150–200°C), triggering the precise breakdown of seams while leaving the rest of the fabric intact. This controlled disassembly process allows for the automatic removal of disruptors—such as zippers, buttons, elastics, and reflective trims—that traditionally hinder textile recycling. By integrating Smart Stitch™, brands and manufacturers can preserve complex garment designs without sacrificing recyclability, directly addressing the fashion industry's longstanding trade-off between design freedom and circularity (Pourhashemi, 2021).

Unlike conventional sustainability recommendations that promote mono-material use and simplified garment structures, Resortecs' approach allows for material diversity while maintaining full recyclability. This paradigm shift moves the industry beyond linear production models toward a truly integrated circular system in which materials are recovered, repurposed, and reintegrated into the textile supply chain.

By embracing Design-for-Disassembly and Active Disassembly, Resortecs is fundamentally reshaping how garments are conceived, produced, and recycled, demonstrating that sustainability and innovation can coexist without compromising design complexity or performance. This shift improves the economics of textile recycling and also aligns with the growing regulatory push for circularity, setting a new standard for how the industry approaches sustainability at scale.

To complement its innovative stitching technology, Resortecs developed Smart Disassembly™, the world's first thermal disassembly system, which ingeniously merges the precision of manual dismantling with the speed and consistency of automated processes. Traditional manual disassembly methods, while precise, are labor-intensive and slow, often resulting in prohibitively high costs for textile recyclers. On the other hand, conventional mechanical disassembly processes lack the finesse to separate mixed materials without contamination, limiting their efficacy.

Smart Disassembly™ bridges these gaps by utilizing controlled thermal processes to selectively disassemble garments, effectively removing disruptors such as zippers, buttons, elastic bands, and reflective trims. The system operates up to 15 times faster than manual disassembly, significantly boosting operational efficiency and throughput. This acceleration is crucial not only for reducing labor costs but also for enabling recycling facilities to handle larger volumes of textile waste, thereby enhancing overall material recovery rates.

Achieving up to 90% material recovery, Smart Disassembly™ effectively doubles the efficiency of standard mechanical disassembly techniques. By maintaining a controlled environment with reduced oxygen levels, the system prevents oxidation, a common issue that leads to fabric degradation during high-temperature processing. This protective atmosphere is particularly important for preserving the integrity of natural fibers such as cotton, wool, and silk, which are prone to burning or weakening when exposed to conventional thermal treatments. The result is recycle-ready materials that retain their quality and structural integrity, making them viable for fiber-to-fiber recycling, thus closing the loop in textile production.

Furthermore, the closed-loop heat recovery system is another cornerstone of Smart Disassembly™' design (Ozsevim, 2023) (Fig. 2). Conventional disassembly methods often involve high energy inputs, contributing to the overall carbon footprint of the recycling process. In contrast, Smart Disassembly™ captures and recycles the heat generated during the disassembly process, using it to power subsequent cycles. This not only reduces the system's energy consumption but also aligns with broader sustainability goals by minimizing the environmental impact of textile recycling operations.

Integrating Smart Disassembly™ into existing textile waste management infrastructures offers substantial advantages for brands, recyclers, and sorters. By automating the removal of disruptors and mixed materials, the system reduces dependency on manual labor, thereby cutting costs and increasing processing capacity. This scalability is essential for addressing the vast amounts of textile waste generated globally and is a critical step toward realizing circular economy principles within the fashion industry. The ability to efficiently separate and reclaim materials from complex, multi-fabric garments represents a transformative shift, positioning active disassembly as a cornerstone technology for the future of sustainable textiles.

Resortecs' innovative technologies have already

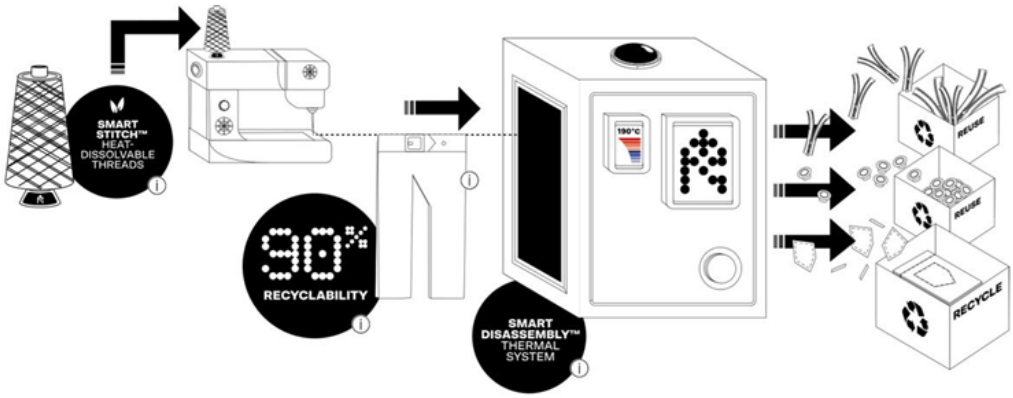

Fig. 02

been adopted by leading fashion brands, demonstrating their applicability at an industrial scale.

- HNST Studio, (https://www.letsbehonest.eu/), the Antwerp-based label dedicated to creating jeans that embody transparency and circularity, has integrated Smart Stitch™ into its denim collection, enabling fully recyclable jeans and reducing the reliance on virgin materials.

- Decathlon has incorporated heat-dissolvable stitching into its ski jackets (https://resortecs.com/decathlon-launches-recyclable-ski-jacket-with-resortecs-technology/) and swimwear, (https://resortecs.com/resortecs-x-decathlon-industrialising-recyclable-swimwear/), ensuring that garments can be easily dismantled at EOL without compromising performance during use.

- Sioen, a leader in workwear production, has partnered with Resortecs to develop protective garments that maintain safety standards while being fully recyclable.

Despite the technological advancements and environmental benefits of Resortecs' Smart Stitch™ and Smart Disassembly™, several economic and structural challenges must be addressed before achieving full-scale industrial adoption.

One of the most significant barriers to widespread adoption of textile recycling technologies is economic viability. Today, most recycling processes remain at Technology Readiness Level (TRL) 5-6, meaning they are in the pilot or demonstration phase rather than fully industrialized. As a result, production costs remain high and unpredictable, making it difficult for brands and recyclers to commit to large-scale investment. Additionally, the low volume of recycled textiles currently processed exacerbates cost disparities. Because economies of scale have not yet been achieved, recycled materials are systematically more expensive than virgin materials, creating a financial disincentive for brands to transition to circular solutions. This economic imbalance remains a key obstacle to large-scale industrial adoption.

Another fundamental challenge is determining who should bear the additional cost of circular textile systems. In a traditional linear production model (produce-use-dispose), costs are typically absorbed by the weakest entity in the supply chain—often garment manufacturers or recyclers, who have the lowest margins and the least bargaining power.

For circular solutions like Resortecs' to be fully implemented, cost-sharing mechanisms must be developed. Potential strategies include:

- Extended Producer Responsibility (EPR), where regulatory frameworks require brands to finance recycling costs rather than externalizing them to lower-tier suppliers;

- consumer involvement through green pricing models, where a portion of the recycling cost is embedded in product pricing, similar to existing eco-labeling schemes;

- and public-private partnerships (PPP), where governments and institutions provide financial incentives, subsidies, or tax reductions for brands that integrate circular solutions.

Without fair cost distribution, the financial burden will continue to fall on the weakest entities, discouraging adoption and limiting circularity's

economic sustainability.
For Smart Stitch™ and Smart Disassembly™ to reach full-scale adoption, stronger infrastructure for textile sorting and recycling must be developed. Currently, most existing facilities are not designed to handle garments disassembled at scale, creating bottlenecks in processing and material reintegration. Moreover, investment in industrial-scale fiber-to-fiber recycling plants remains limited. Even as regulatory pressure increases, such as the mandatory textile waste sorting regulation set to take effect in 2025 in the EU, the financial ecosystem has yet to catch up. Resortecs' collaborations with brands like Decathlon and Sioen demonstrate progress toward systemic adoption, but broader public and private investments are needed to scale up recycling capacity and reduce processing costs.
Even if brands adopt circular solutions, market demand for recycled textiles remains inconsistent. Consumer preferences often prioritize cost and aesthetics over sustainability, meaning that high production costs of recycled textiles are difficult to justify in competitive pricing strategies. A shift in consumer behavior—supported by eco-labeling, awareness campaigns, and regulatory incentives—is essential to drive demand for circular fashion at scale. Without this market pull, even the most advanced recycling technologies risk stagnation due to insufficient adoption.
For Resortecs and similar innovations to achieve full industry integration, a multi-stakeholder approach is required, addressing technological, economic, and regulatory barriers simultaneously. While the Smart Stitch™ and Smart Disassembly™ systems provide tangible technical solutions, overcoming economic uncertainty, infrastructure limitations, and cost distribution inequalities remains the next critical challenge for scaling circular textile solutions.
The creation of a textile waste management consortium in Benelux and France, led by Resortecs, represents a crucial step in accelerating industrial adoption. This initiative will bring together manufacturers, collectors, and recyclers to establish an economically viable circular system, with Smart Disassembly™ lines projected to process 3,000 tons of textile waste annually by 2026.
The findings of this study reinforce the importance of embedding recyclability at the design stage rather than relying solely on end-of-life waste management strategies. Resortecs' heat-dissolvable thread and thermal disassembly system showcase a scalable, systemic approach to sustainable fashion, challenging traditional linear production models by making textile circularity both feasible and cost-effective.
Furthermore, the successful implementation of Smart Stitch™ and Smart Disassembly™ across various textile categories—apparel, workwear, footwear, and home textiles—illustrates their broad applicability and potential for industry-wide transformation.
Ultimately, this study highlights that Resortecs' solutions are not just technological innovations, but catalysts for systemic change—empowering designers, manufacturers, and recyclers to embrace circularity at scale.

CONCLUSIONS

In conclusion, the findings from this study underscore the transformative potential of Resortecs' heat-dissolvable thread and Smart Disassembly™ system in accelerating circularity within the fashion industry. By integrating Design-for-Disassembly (DfD) and Active Disassembly principles, Resortecs enables brands to maintain design complexity while ensuring full recyclability—overcoming the long-standing trade-off between creativity and sustainability.
This case study highlights how technological innovation in garment construction can directly impact material recovery, waste reduction, and the transition to a circular textile economy.
Resortecs' approach demonstrates that sustainability can be embedded at the design phase rather than being an afterthought at the end of a product's lifecycle. By facilitating efficient garment disassembly, improving fiber-to-fiber recycling, and reducing dependency on virgin materials, this innovation provides a compelling model for industry-wide adoption. Moreover, it aligns with emerging regulatory pressures, such as Extended Producer Responsabilityy (EPR) and mandatory textile waste sorting, reinforcing the urgency for scalable circular solutions.
However, the widespread adoption of circular production models remains dependent on overcoming key challenges, including economic feasibility, infrastructure development, and industry-wide collaboration. Cost distribution across the supply chain, investment in textile sorting and fiber-to-fiber recycling facilities, and shifts in consumer behavior are critical factors

shifts in consumer behavior are critical factors in determining the success of these solutions. Resortecs' ongoing collaborations with brands like Decathlon, Sioen, and HNST Studio highlight the real-world applicability of its technology, yet further investments are needed to scale its impact. The present study lays a foundation for future research by illustrating how design innovation can catalyze sustainable practices within the fashion industry. Future investigations can build upon this foundation to explore the scalability of emerging solutions, their application across diverse garment types, and their integration into existing manufacturing processes. Additionally, further research could explore consumer acceptance and market readiness for such innovations, offering insights into the effective promotion and implementation of sustainable products.

Moreover, the insights derived from Resortecs' approach highlight the critical importance of interdisciplinary collaboration in advancing sustainability in fashion. Engaging with designers, material scientists, and industry stakeholders is essential to refining new sustainable solutions and ensuring their feasibility at scale. This collaborative approach should extend to educational institutions, where sustainability principles and innovative design practices can be embedded into curricula—preparing the next generation of fashion professionals to prioritize circularity.

Designers are positioned at the forefront of these changes and play a pivotal role in shaping whether such technologies gain widespread adoption or remain confined to niche applications. Their decision-making—balancing cost, aesthetics, and production feasibility—directly influences the success of innovation in the fashion industry. By embracing new materials and disassembly technologies, designers can lead the transition toward circularity, ensuring that sustainability does not come at the expense of creativity.

Ultimately, this article demonstrates that a simple change in thread can foster design innovation, not merely as a functional or aesthetic enhancement but as a powerful lever for systemic change within the fashion industry. Resortecs' Smart Stitch™ and Smart Disassembly™ challenge linear production models, offering a scalable, economically viable path toward sustainability. By embedding recyclability at the core of garment design, these innovations set a new benchmark for responsible fashion—ensuring that circularity becomes a standard rather than an exception.

CAPTION

[Fig. 01] Coding Process (D'Itria, 2024).

[Fig. 02] Resortecs Technology (Resortecs, 2022).

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