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RECYCLED TEXTILES: EVOLVING DESIGN-DRIVEN PRACTICES FOR CHANGING THE CIRCULAR FUTURE OF THE FASHION SECTOR

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Abstract: *In recent times, waste materials such as deadstock or used clothing have captured the fashion industry's attention. These materials have been the subject of studies to design sustainable production systems and new manufacturing techniques, intending to approach a circular economy model. In this context, the fashion industry has implemented strategic, design-led actions to prevent waste and promote recycling and recovery actions. Recycled textiles are fertile ground for fashion experimentation that, starting from the circular economy concept, can involve the entire textile supply chain: all the different actors working together proactively to encourage the establishment of industrial symbiosis systems between the districts. An excursion among the ideas and techniques applied to this field can show the possibilities of sustainable material-led approaches that can make a more positive future thrive.*

Keywords: *circularity, fashion design, industrial transformation, sustainability, recycling*

1. INTRODUCTION

Today, the production and consumption actions are starting to involve a systemic approach guided by design and follow a defined pattern that supports industries in meeting the needs of today, preserving the future ones [1]. This systemic approach is particularly evident in the fashion sector and represents the intersection between fashion, design, and sustainability [2]. Fashion Design for Sustainability (FDfS) is the branch that investigates this specific point of intersection. This study of fashion, design and sustainability began in the early 2000s informed by several scholars [3-8]. They built the framework focusing on the environmental and social implications of the fashion sector, offering new examples and approaches. Prof. Fletcher's work "Design Journeys" marked a turning point expanding the sector boundaries and going beyond the simple interest in the material or technical characteristics but enhancing the physical and emotional well-being of people, as well as contributing to the use of resources ethically and responsibly without destroying social and ecological balance [9]. The fashion industry is now translating these concepts into tangible actions by developing greener design concepts, paying attention to materials choice, performing greener processes, involving ethical change, and empowering communities [2].

Therefore, the sustainable dimension of fashion contemplates the whole product lifecycle pattern the items might create from the design phase to the end of life.

Fashion is investing intending to green the industrial machine processes to repair social and business practices and create a new way of viewing and living fashion [10].

According to those mentioned above, how can fashion move forward to achieve the objectives set?

The fashion industry is implementing different circularity practices which aim at incrementally reducing the harm of the current linear model considering waste alternatives: Repairing, reusing, remaking, and composting [11].

In the last few years, waste of industrial production and consumption, such as deadstock or used clothes, both of textile matrix and coupled with plastics, has been studied. These studies aimed to design sustainable production systems and new manufacturing techniques to approach a circular economy model [12-14].

These strategic actions, guided by design, are intended to prevent waste and promote recycling. These efforts are coherent with the necessity to positively impact People and the Planet, stressing the importance of rethinking research and design (R&D) strategies and converting the old linear supply chain model into a new circular one [15].

Recycled textiles are a fertile ground for fashion experimentation that, starting from the concept of circular economy, encompasses the entire textile supply chain, involving the different actors along the supply chain in a proactive way to encourage the establishment of a system of industrial symbiosis between the districts.

A plethora of fashion and textiles companies are currently working on disruptive and ecological innovations to produce regenerated materials with high sustainable performative characteristics [16]. An excursus among ideas and techniques - that have been applied to this field of research - can show the possibilities enabled by the design-led approaches which hack the present to create the conditions of the future [17].

The proposed paper investigates, with a view to the materials recovery, the valorisation of waste. At the base of the sourcing activity, there is the collection by companies of unsold, deadstock, and processing waste of some, which are circularly recovered into yarns, clothes, and accessories. The presented shift to circularity is consistent with the times as the global fashion industry needs to consider the scarcity of essential and finite resources. Resource-dependent enterprises need to seek alternative ways that allow for sustainable and continuous sources. The linear production that characterizes modern business models is unsustainable and requires a system of industrial symbiosis along the supply chain [17]. It is not just a technical issue. There is a need for a design, management, and optimization of material-driven activities to promote new strategic practices that can prevent waste production and, through materials recycling, drive the fashion sector's passage to a positive model of consumption.

Starting from the presented state of the art in Fashion Design for Sustainability, the paper investigates the evolution of production practices in fashion and textile recycling. Particular attention is paid to the design-driven transition of the textile industry from a linear to a circular model. A design-driven change explores the potential positive impact of design on competitive advantage, addressing new product meanings. De Goye et al. [18] states that this development is guided by new knowledge on different contexts including,

2. MATERIALS AND METHODS

The paper aims to present the result of research conducted into how fashion and textiles companies, particularly those working in the European area, are focusing on implementing their recycling practices and performances through the adoption of the technological medium.

Methodologically, the approach consisted of four main stages to co-construct new knowledge: the first phase of desk-based research of the current recycling practices in the fashion industry; the second phase mapped company and designers who are working on disruptive and ecological innovations for the production of regenerated materials with high sustainable performative characteristics identifying the best practices; the third phase of in-depth analysis of the recognized best practices; and the last phase integrated all the collected

data to define the evolving design practices which are changing the circular future of fashion sector.

The initial desk research phase made it possible to identify a varied and fragmented panorama of SMEs carrying out virtuous practices on the Continent.

The further phase of mapping led to the identification of 202 companies located in 23 nations worldwide, which have distinguished themselves for having reached a mature level within their production practices concerning the theme of sustainability (figure 1). All the identified practices were operating in the fashion or textile field, enhancing sustainable and responsible practices which considered both People and the Planet.

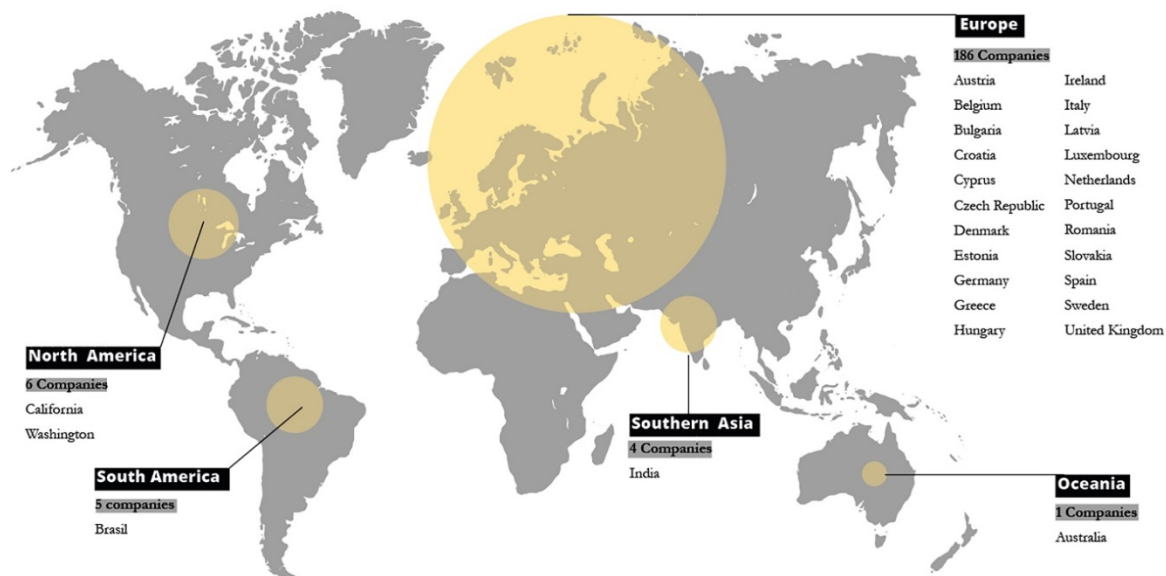


Figure 1. Map of the sustainable company analysed

The composition of the companies was heterogeneous. They were players implementing sustainability in their action, not only in the design field but also in the management and technology/engineering. Of the 188 companies mapped, 35 were selected as case studies. The case studies aimed to narrow down a vast field of research into easily researchable topics. They were chosen according to several criteria:

- Level of maturity to understand who was moving from greenwashing to become feasible and strategic.
- Dimension, since the study was intended to be as representative as possible, the authors wanted to have cases from all ranges of companies (from micro to big);
- Textile recycling technology selects representatives of the different methods and technologies for textile waste recycling to understand the state of the art (figure 2).

All these enterprises are today relevant for the methods they pursue implementations of sustainable practices within their system, often adopting a technological transformation approach as support.

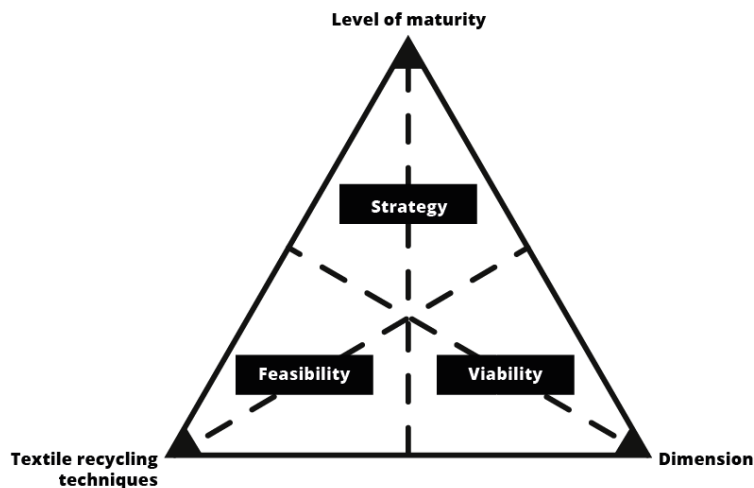


Figure 2. Case studies criteria selection

The following phase consists of a further analysis through 5 selected face-to-face interviews with representatives from 5 companies that had previously distinguished themselves as best sustainable practices.

The interviewed were selected according to:

- their background;
- company history and reputation;
- their tangible outcomes;
- sustainable initiatives that efficiently improved their performances (reports, stakeholders' evaluations, certifications), and communication.

All these case studies showed a desire to evolve and respond to the new needs of the surrounding environment, evidenced by their path towards circularity through recovering practices.

The next phase interpreted the collected data exploring how a positive transformation in the fashion system is possible by implementing specific design-driven aspects. This step allowed the authors to understand which criteria a company working on design-led recycling practices must meet. These aspects are today related to materials, and they lead towards circularity by imagining and implementing processes with high sustainable performative characteristics in two particular areas: recycling, converting waste into new materials by destroying it and then giving it a new life; and regenerating, reusing scraps and waste, without destroying them, to create products that have more value [20].

3. RESULTS AND DISCUSSIONS

From the research emerged a clear overview of current recycling practices. To date, there are two methods of textile recycling: mechanical and chemical. Mechanical recycling is the recycling of textiles into fibres without the use of chemicals. During this process, the used garment is shredded and carded to extract the fibres from the fabric. This fibre can then be spun to make yarn for fabric or knit. Chemical textile recycling adopts a series of chemical processes to depolymerize/dissolve the thread to make a monomer/solvent, create a new fibre compound, or extract a combination from a mix. These processes' end products are often of the same quality as their virgin counterparts, with no loss of physical properties through the recycling process. Both these practices are carried out to achieve the goal of a circular economy. This goal is consistent with what the European Union has established: By 2025, end-of-life textiles must be collected separately and recycled so that new fibrous

material with properties similar to virgin material can be produced [19]. This goal is already technically feasible for selected mono-material waste textiles of a single fibre type, the problem is multi-material textiles. To date, there are no technologies that can allow a sustainable transformation of these materials. While, in cases where textile blending is necessary, it will be mandatory to design new forms of recycling capable of separating different fibre materials directly or through selective processing of individual fibre materials into useful chemicals. Furthermore, as Piribauer and Bart [20] reported, since any recycling process to be implemented by a private company must be profitable, a bonus-malus system based on extended producer responsibility should be considered.

In addition, design can play a crucial role in enabling easier and more effective recycling methods. Below is a list of the significant design actions highlighted by the research:

- Design for recycling, avoid mixing to allow materials to return to their cycle.
- Design for mono materials, use sewing threads with the same composition as the garment material.
- Consider sustainable colours, dyes, finishes, and prints and avoid toxic chemicals.
- Design for sustainable systems; since the selection process is still manual, consider switching to an automated process.
- Design for people, educate consumers.

The presented results address how design drives solutions that lead towards circularity. A new paradigm by imagining and implementing processes with high sustainable performative characteristics. This move towards circular models is happening in two specific areas:

1. Recycling means converting waste into a new material by destroying it and then giving it a new life.
2. Regenerating means reusing scraps and waste without destroying them to create valuable products [21].

Recycling responds to the new pace of consumption in the Western world which follows fast and unsustainable patterns. This unsustainable path has led to an increase in disposed of clothing and textiles rather than being reused or recycled. According to data, 85% of clothing and textiles end up in landfills, even though 95% can be reused and recycled [22]. Once in landfills, there are two possible scenarios. First, natural fibres can take a few weeks and/or a few years to decompose, releasing methane and CO₂ gas into the atmosphere [23]. In the second scenario, synthetic textiles are designed not to deteriorate and may release toxic substances into groundwater and surrounding soil [24]. According to the processed data, textile recycling can be a solution to these issues and offer both environmental and socio-economic benefits: decreasing the need for landfill space, bearing in mind that synthetic fibre products do not decompose and that natural fibres can release greenhouse gases; avoiding the use of virgin fibres; reducing energy and water consumption; impacting on the pollution of land and resources while preserving the health of people and workers [25]. Regenerating addresses the fact that today the textile industry is a vast and high-impact industry. Fibres are the primary raw material for textiles, and their manufacture produces tremendous environmental and social impact, which is necessary to find sustainable alternatives [26]. In this context, the case of cotton is emblematic. Cotton is the most widespread profitable non-food crop in the world. Its production provides income to more than 250 million people worldwide and employs nearly 7% of all labour in developing countries. About half of all textiles are made from cotton. Hence, cotton's global reach is vast, but current cotton production methods are environmentally unsustainable, undermining the industry's ability to maintain future production [27]. In the presented scenario, textile

manufacturing industries need to design new resources, technologies, and environmentally and socially adequate processes.

From the collected data emerged how regenerated fibres may represent a solution. In recent years, they proved to be a viable alternative that has overcome the limits linked to the environmental and social dimensions. Regenerated fibres address the chemical issues in two ways:

- using innovative solutions that make it possible to beat impacts and produce in a way that is compatible with both people and the environment [28];
- rediscovering historical techniques whose application can be a positive and sustainable added value for companies and their production [2]. These productive practices support an industrial shift to circularity which is consistent with the times.

The global fashion industry needs to consider the scarcity of essential and finite resources. Resource-dependent industries need to seek alternatives. As previously stated (see Section 1), the linear production that characterizes modern business models is unsustainable and requires a system of industrial symbiosis along the supply chain. The introduced discussion will be enhanced by presenting two case studies selected among the best practices identified by the research. According to the strategies mentioned above, companies are operating to innovate their production practices and waste management to improve their circular performances and develop new sustainable alternatives. The following sections will enhance the discussion introduced above by presenting two case studies selected among the best practices identified by the research. The purpose of using case studies is to focus on one case but simultaneously consider their entire context. Thus, their illustration will include many variables and qualities sufficient to delineate the research field and offer actual data [29].

3.1. Destroying materials for giving new life: The Ecoalf case

Ecoalf is a Spanish apparel label committed to creating an alternative business model to preserving the Planet. Ecoalf uses a high proportion of eco-friendly materials concentrating their R&D strategies on recycled materials limiting the number of chemicals, water, and wastewater used in their production. Their garments are made from recycled materials, such as plastic bottles from the bottom of the ocean, recycled nylon, cotton, and wool, and recycled used tires. Also, they are an example of industrial synergy as their products are made through partnerships in different countries such as Spain, Portugal, Taiwan, or Japan, among others. The aim is to create products that promote sustainability among consumers seeking design and quality [30]. Their sources characterize the materials: Ecoalf uses the recycled plastic trash collected from the oceans. The company has been interrogated specifically on their initiative "Upcycling the Oceans". This initiative – co-founded by EU Commission- allow them to recycle over 70,000,000 plastic bottles and 60 tonnes of fishing nets: with 70 plastic bottles and 135 grams of nets, the company can create one meter of fabric [31]. The project started in 2015 on the initiative of the Ecoalf Foundation together with the HAP Foundation. They aimed to help remove marine debris from the bottom of the oceans thanks to the support of anglers: recuperating the plastic trash that is damaging the sea and transforming it into top-quality yarn to produce their garments.

The company has come a long way in the last six years, mainly concerned with the quality of the final materials. The main issue was the low and inconsistent quality of the debris recovered by the fishermen. They overcame these complex barriers thanks to crucial investments in R&D. Their work focused on recycling PET plastic bottles - which now constitute the primary raw material of Ecoalf. Their innovative process transforms old plastic bottles into flakes and pellets to obtain a high-quality, 100%

polyester recycled filament. This technology offers a successful alternative to the use of the Planet's natural and finite resources. Using recycled materials, the brand saved over 20% in water, 50% in energy, over 60% in greenhouse emissions, and holds 27% in terms of natural resources [32]. Ecoalf is now meeting the challenge of recycling ocean plastic waste, transforming it into a sustainable and profitable resource. They have been selected and introduced in this paper as sustainability pioneers. Their practices succeeded in creating the first generation of recycled products with the same quality and design as the best non-recycled ones. This achievement results from a design-driven innovation that started from the company's culture and their vision of doing things. They explore how values and aspirations could evolve. This culture and vision do not come from *the market but creates new markets; they do not push new technologies but give rise to new meanings* [33]. Ecoalf's winning practice, which is today replicable, is an example of the industry's positive conversion. This conversion is based on the company's purpose of starting recycling practices that could convert waste into a new material giving it a new life. Ecoalf proves that companies can manage this process to redefine dominant meanings and thus bring long-term competitive advantage [34].

3.2. Preserving materials for giving new value: The Evrnu case

Evrnu® is an American textile innovations company creating a circular ecosystem. The company became famous in the international textile scene thanks to its partnership with Levi Strauss & Co. This collaboration aimed to develop the world's first jeans made from discarded cotton. The company develops a patented technology to create engineered fibres characterized by high performance and minimal environmental impact made from discarded clothing. Evrnu® primary objective was regenerating cotton waste - post-consumer (worn and used garments) cotton waste - to create premium fibres. Today, the fashion industry is estimated to create 92 million tons of textile waste annually, and landfilled waste produces methane over 20 times more harmful than CO₂ [32]. For these reasons, the company aims at contributing to minimize textile waste and address natural resource vulnerability. To reach this goal, the company researched and developed an innovative technology that purifies cotton garment waste, converts it to a pulp, and extrudes it as a new fibre to create premium textiles.

Furthermore, they build a closed-loop system that creates positive synergies between pivotal actors along the supply chain as producers, retailers, and consumers. Evrnu's mission focuses on the idea that taking waste and turning it into something else is meaningless if that something else has a fate that ends up in a landfill or incinerator: companies just created a delay to the inevitable waste [33]. What characterizes the process developed by Evrnu is its creation of minimal negative environmental impact. Their technology uses 98% less water than is required to produce virgin cotton. In addition, Evrnu eliminates 80% of the polluting emissions typical of manufacturing these products and can be remanufactured multiple times [34]. Evrnu has been selected as a case study for their environment-sparing alternative for the world's highest-demand fibres such as cotton, polyester, and rayon. From a design-driven perspective, their work gives new meaning to waste. They can meet latent needs and desires and explore new markets, developing innovative products differently from the past and showing a new future [19]. Their practices are laying the foundations for closing the loop on fashion overproduction/waste.

4. CONCLUSIONS AND FUTURE RESEARCH

This paper discussed the current scenario of the recycling textiles dimension in the fashion and textile sectors. Here are reported innovators, in the two identified categories, through the use of case studies. The discussion informs directions towards a

circular paradigm enabled by the adoption of design-led practices in the European fashion industry. The main methods highlighted how design is crucial in driving a continuing evolution to a more sustainable context. The paper suggests that the link between circularity and innovation-driven innovation in the fashion field is related to systemic practices. Such practices nurture an industrial symbiosis along the supply chain that considers actions carried out to extend product time in the system, transforming them or assigning them to another loop or sector. These practices are now contributing to the circular passage thanks to their role in preserving non-renewable resources and eliminating waste.

Future points of reflection stimulated by this work may concern possible directions for the evolution of recycling technologies and the exploration of the role of design in developing systems to improve collection and recycling of used textiles to follow up amounts and quality levels of collected, used materials.

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