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Implementation strategies for circular business models in emerging fashion start-ups

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Abstract

Due to industrialisation and the explosion of the "fast fashion" phenomenon, the production of textiles and clothes has more than doubled in the last two decades and is expected to increase by a further +30% in the next 10 years (*Textile Exchange Report, 2020*).

Worldwide, only 20% of the clothing produced is recycled, while the remaining 80% is incinerated or landfilled (*Koszewska et al., 2018*). As a result, the fashion industry is considered the second most polluting sector in the world and must evolve urgently.

Therefore, a "paradigm shift" is necessary in order to implement sustainability and circular economy principles in this market system which has such a tremendous economic and environmental impact.

Different techniques for the production, recycling and reuse of textiles have recently been developed, but they need to be improved and opened up not only to multinational brands but also to small emerging businesses.

Hence, this literature review attempts to provide an overview of the most innovative and recent techniques for the production, recycling and reuse of textiles and clothes available on the market today with relevant case studies. In addition, it offers a number of practical tools useful for the transition from linear to circular business models particularly for fashion enterprises.

Finally, it suggests an involvement of all major stakeholders throughout the value chain to implement sustainability and thus achieve a shared and synergic economy; generating holistic multiple-added value and business models that are resilient to change and future-proof.

Layman's Abstract

In recent decades, the production of textiles and clothing has grown exponentially, leading to the generation of massive volumes of waste and the emission of huge quantities of greenhouse gases. Today, it is of paramount importance to find holistic sustainable solutions to reduce the environmental impact this sector causes. For this reason, this literature review provides an overview of the burden of pollution caused by textile and fashion companies and the existing solutions available.

Finally, in order to increase the environmental sustainability of the entire sector, several tools and strategies derived from the circular economy principles are offered to implement circular business models in companies of all scales and natures.

Introduction

In recent years, increasing attention has been focused on the impact that companies, especially multinationals, have on the environment, society and the entire economic system.
Indeed, the steady increase in global population, the effects of climate change and the resulting scarcity of resources such as water, land and energy has forced companies to start paying more attention to sustainability.
In particular, the clothing industry is among the most polluting worldwide. In fact, as was stated by the French Minister of the Environment, Brune Poirson, on 13 May 2019 at the Copenhagen Fashion Summit: *"The fashion sector is the second most polluting industrial sector in the world. We need to give it a direction"*. In fact, the damages it causes to the planet, unfortunately, are visible at different stages of the product life cycle. Indeed, extracting raw materials requires large quantities of energy, an extensive use of water and soil. In addition, several chemical treatments are necessary during the production process, resulting in the dispersion of huge amounts of contaminants into the biosphere. Furthermore, the transport and distribution of products and materials throughout the global value chain requires high fuel consumption with direct and indirect greenhouse gas emissions into the atmosphere. Finally, the use and end-of-life phases of products involve their major environmental impact by consuming large volumes of water, energy and chemicals, as well as dispersing massive proportions of microplastics into the ecosystem and consequently throughout the food chain (*Jacometti, 2019*). Globally, only about 20% of textile waste is recycled, while the remaining 80% is landfilled or burned (*Koszewska et al., 2018*). Moreover, due to the actual lack of a viable technology, only less than 1% of fabrics from clothes are recycled back into garments (*Ellen Macarthur Foundation, 2017*). Therefore, nowadays the transition to a more circular economy (CE) is crucial.
The CE aims to develop economic systems that reduce the consumption of resources and generation of pollution, as well as minimising the waste of energy. CE is defined as a restorative or regenerative industrial system by intention and design, which uses and reuses natural resources as efficiently as possible, and recovers value across the entire products' life cycle (*McKinsey et al., 2016).* As a matter of fact, the transition to a more sustainable and circular economy for the clothing sector requires the renewal of four major pillars: i.e. new materials and product design strategies, improved business models, reverse global networks and technologies, and supportive conditions determined by international policymakers and governments (*Planing, 2014; Ellen MacArthur, 2015*). Moreover, the core values of the CE, represented by the so-called 3 R's (reduce, reuse,

recycle), combined with a regenerative component capable of reintegrating resources into the value chain, should be applied throughout the entire cycle of manufacturing, consumption and return of goods and materials. This needs to be embraced by all market stakeholders, thus creating a paradigm shift and a more responsible shared economy (*Prieto-Sandoval et al., 2018*).

1. Material and Methods

A literature review was conducted in order to analyse the most recent publications and practices adopted by companies and organisations in the fashion and textile industries to reduce their environmental impact. With a focus on the application of sustainable production and distribution strategies in order to provide dynamic regenerative holistic business models applicable to both large multinationals and small innovative start-ups.
To conduct this literature review, the databases chosen were mainly: Google Scholar and ScienceDirect, and included the analysis of documents from multiple foundations (such as Ellen Macarthur Foundation, H&M Foundation) and organisations such as United Nations, Food and Agriculture Organisation and Society of Environmental Toxicology and Chemistry.
The scientific articles were chosen in a preferred time frame ranging from 2015 to 2022 in order to provide the most updated and relevant data possible.
The keywords used for the search were "Circular Economy", "Fashion Industry", "Sustainability", "Circular Business Models", "Regenerative textiles", "Textile Recycling".
With the above-mentioned parameters, more than 17,000 scientific articles were found.
Of these, about 100 were workable and about 50 were subsequently used to write this literature review. In fact, only currently valid articles, books and manuals that had a systemic approach to address the concerned problem were employed. The ones that introduced case studies, references and practical tools to identify, manage and improve the sustainability of the relevant sector. Taking into account the vastness of the issue and the feasibility of its resolution; for both established companies and emerging start-ups with a tight budget.

2. Findings

2.1 (Fast-) Fashion industry

The fashion industry is a $1.3 trillion global business, providing employment for over 300 million people all around the world (*BOF & McKinsey, 2019*). This highly competitive market is mainly dominated by multinational brands operating in a rapidly changing environment characterised by increasing uncertainty due to geopolitical and economic instability that has affected the market since the 2008 financial crisis (*Gazzola et al., 2020*). In the last two decades, the production of clothes and garments has practically doubled. This is mainly due to two factors: the shift of production to emerging or developing countries with low manual labour prices, and the development of the now well-known "fast fashion" phenomenon (*Singh 2017; Anguelov 2016*).

"Fast-fashion" can be defined as *"the retail strategy of adapting merchandise assortments to current and emerging trends as quickly and effectively as possible"* (*Sull & Turconi, 2008*). This, combined with the steady growth of the emerging middle class in developing countries, has allowed an increasing number of people to buy more clothes at lower prices; and to treat these "fast-clothes" as "almost disposable". Throwing them away after only an average of 7 or 8 times they have been worn (*McKinsey&Co et al., 2016*).
According to the New York Times, the famous multinational clothing brand Zara, through its vertically and extremely far-reaching supply chain, is able to export garments 24/7, 365 days a year. As a matter of fact, on average a *Zara* garment takes less than two weeks to go from its designing stage to being ready for sale in shop (*Bhardwaj et al., 2010*). Besides the fact that toxic chemicals and fossil fuels are used throughout the value chain. Clearly, this practice is not sustainable and imposes enormous pressure not only on the designers' inventiveness, but also on the entire manufacturing and distribution chain. In fact, this production pace is only economically feasible by relocating the fabrication process to countries with low labour costs and where, unfortunately, worker protection laws do not exist or are not respected (*Gazzola et al., 2020*).

2.2 Waste in the Textile and Fashion sectors

World fiber production has more than doubled in the last 20 years. Growth has been steady over the past decades, with China and European Union being the two largest exporters of textiles and clothing. Globally, textile fiber production increased from 23.9 million metric tonnes (MMT) in 1975 to 111 MMT in 2019, and this trend is expected to continue to grow by +30% over the next 10 years, reaching 146 MMT in 2030 if business continues as usual (*Textile Exchange Report, 2020*). Historically, cotton has been the most widely produced and used fiber in the world (*Juanga-Labayen et al., 2022; Gazzola et al., 2020*). However, from the mid-1990s until today, synthetic fibers have vastly surpassed cotton in production volumes and utilisation. Indeed, as can be observed in *Fig. 1*, synthetic fibers such as polyester, polyamide and others accounted for 63% of world fiber production in 2019. In fact, in 2019 only polyester occupies around 53% of the market, with cotton holding the second place at around 23%. Finally, wool accounted for only around 1% of the global market share, other plant-derived fibers such as linen, jute, hemp only around 6% and silk & down less than 1% (*Textile Exchange Report, 2020*).

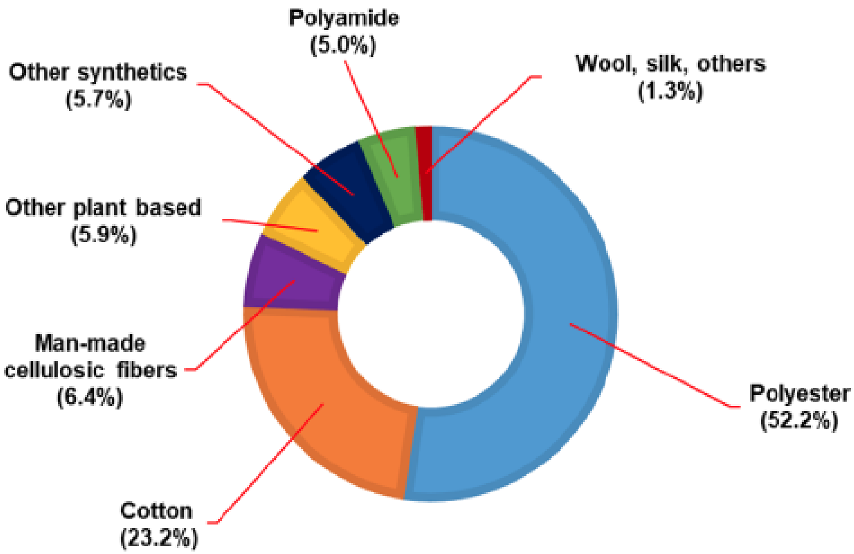

Figure 1: *Global fiber production share in 2019 (Juanga-Layen et al., 2022; Textile Exchange Report, 2020)*

Indeed, the massive increase in demand for clothes and the drastic reduction in their use time - which has fallen by 36% in the EU and 70% in China in recent decades (*Zhang et al., 2016*) - does not, however, stand up to overproduction. In fact, it is estimated that only 30% of the clothes produced are sold at list prices, the other 30% go on sale and the remaining 40% either stay unsold or fail to reach the shops (*Danigelis, 2020*).

Textile waste is considered to be material scraps discarded from the manufacturing process. Waste from textile fiber production is divided according to the source from which it comes, as follows:

1) **Industrial waste**: viewed as "clean waste", encompasses discards from the manufacturing process, generally the easiest waste to recycle as the fabric scraps are usually of the same colour and material.

2) **Pre-consumer waste**: generally consisting of finished but defective products that cannot be so sold. Typically a waste that is difficult to recycle or reintegrate within the production chain due to the probable presence of different types of fibers (often natural and synthetic intertwined), presence of metallic trims and different fiber colours.

3) **Post-consumer waste**: generated by the consumers themselves after purchasing the clothes. This category is the one with the worst environmental impact in terms of resource use (water and energy) due to washing; as well as the constant generation and dispersion of microplastics in the environment (*Koszewska, 2018*).

As a matter of fact, just as the production of fibers has grown sharply over the last decades, the generation of textile waste has also followed the same trend (aggravated by the reduction in the lifespan of products before being thrown away). In fact, according to *Eurostat 2014* data, in the period between 2004 and 2012 the generation of textile waste per capita grew remarkably in several European (or former European) countries such as: UK (from 4 to 19 kg per capita, Germany (from 2 to 4 kg per capita) and Austria (from 4 to 5 kg per capita). However, fortunately, other European countries have managed to reverse this trend. For example, in Portugal textile waste per capita went from 45 kg to 6 kg, in Italy from 14 kg to 7 kg, in Belgium from 59 kg to 16 kg. And the record was achieved by Romania, which succeeded in moving from 12 kg to 1 kg per capita (Koszewska, 2018). In addition, to compound the heavy influx of textile waste, there is the major problem of how to manage it at the end-of-life stage. Indeed, the current available options are: reuse (repair and resale), recycling, incineration (to recover and generate thermal energy) and landfill disposal. However, globally there is neither an effective reverse collection network nor efficient recycling technology for the most commonly circulating fibers and textiles. In fact, only 20% of apparel waste is ultimately collected worldwide for reuse or recycling, while the residual 80% is landfilled or incinerated (*Denigelis, 2020; Lewis, 2015*).

2.3 From Linear to Circular Business Models

The 2030 Agenda for Sustainable Development, adopted by all members of the United Nations in 2015, envisages 17 Sustainable Development Goals (SDFs) to be achieved by 2030 to improve health and education, reduce social inequality, and promote economic growth; while at the same time tackling climate change by preserving the ecosystem and the precious biodiversity that populates it (*United Nation website).* Therefore, in order to achieve these 17 SDGs, the transition from a linear system of industry to a more circular one that introduces new business models and manufacturing processes is imperative (*Ellen MacArthur Foundation, 2013*).
Indeed, to succeed in the transition towards a sustainable economy, it is essential to focus on the economic feasibility of certain initiatives, as technological and scientific innovation alone are not enough if not supported and ensured by complementary business model innovation (*Chesbrough et al., 2002*).
Hence, to improve their environmental impact, companies have to significantly reduce energy exploitation, optimise resource consumption and minimise waste. In this way, circularity would subverts the traditional linear business model, leading companies to focus on managing resources in markets rather than constantly just producing (*Peeples, 2008; Claiborne, 1972*). Indeed, a paradigm shift is urgent, in order to properly align the importance of economic development with the protection of the environment and the inestimable value of its resources. This requires a multi-disciplinary approach that designs an economy capable of regenerating itself, based first and foremost on the use of organic or renewable materials, which at their end-of-life stage re-enter the ecosystem, but also on (inevitable) technical or non-renewable synthetic materials, created to cycle from production to consumption with the least possible loss of quality and waste of resources (*Gazzola et al., 2020*). However, new circular business models must present also a comprehensive systemic strategy of solutions that go beyond just the selection and employment of suitable materials. This regenerative approach based on the core values of the circular economy generally includes the following main principles:

- Using materials and processes that nourish or feed the planet instead of destroying it by negatively affecting its biodiversity

- Design for reuse/ value creation from the end-of-life phase of products
- Create resilient products and systems through diversity
- Use energy from renewable sources
- Maintain a holistic system view
- Symbiotic cooperation between departments, sectors, and international institutions. Closing the loop, merging the end of one process/product to the beginning of the next. (*Lewandowski, 2015*)

Furthermore, in order to implement circular business actions, the guiding elements of the so-called *ReSOLVE* framework (showed in *Tab.1)* should be applied:

Regenerate	i.e. using renewable energies, resources and materials.
Share	Sharing products substantially extends their life cycle, reducing overproduction and waste (e.g. buying second-hand, repairing etc..).
Optimise	Employing new technologies and innovative strategies to boost performance of products and services to reduce resource waste and labour.
Loop	In accordance with the principle of circularity, keeping resources in the life cycle as long as possible; using techniques such as remanufacturing, recycling, and anaerobic digestion to maintain value preferably in closed loops.
Virtualize	Appling new IT technologies to convert physical objects into digital ones, such as books, music, but also digital clothes (Non-Functional Tokens, NFTs) in the new and increasingly popular metaverse.
Exchange	Replacing outdated production/marketing/distribution/consumption methods and techniques with new ones more circular, sustainable and long-lasting.

Table 1*: ReSOLVE framework (Foundation E. M., 2015)*

Moreover, there are two additional tools for evaluating a company's business model that allow it to be improved, reducing waste and achieving gains that are not only economic but also environmental if properly integrated. These are the *Business model canvas (BMC*) and the *Value proposition canvas (VPC*).

The *Business Model Canvas* as defined by *Ostrewalder* and *Pigneur* is an extremely useful tool used by companies to analyze and evaluate business models in detail which is based on 9 building blocks (*Osterwalder et al., 2005*) that typically are:

1. **Value Proposition** that seeks to solve a customer need/problem by generating added value and revenue.
2. **Key Activities** that must be accomplished to offer the service/product.
3. **Key Resources** as the assets needed to provide the aforementioned elements.
4. **Key Partners** as the network of partners, stakeholders and suppliers that enable the implementation of the business model, ensuring its success.
5. **Customer Relationship** that a company or organisation establishes with its specific customer segments.
6. **Channels** that an organization or company uses to communicate, deliver, and sell the value proposition. Can be of two types: direct (owned by the company) or indirect (belonging instead to the company's partners).
7. **Customer Segments** which identifies the group of customers to whom the value proposition is addressed.
8. **Revenue Streams** is used to describe how the company or organization intends to obtain revenue from the sale of the products/services it offers to a specific customer segment.
9. **Cost Structure** includes all the costs of the business model implementation. It is often left as the last block since it is derived almost directly from the structure of the blocks related to Key Activities, Key Partners, and Key Resources (*Johnson et al., 2010; Barquet et al., 2013; Lewandowski, 2016*).

In addition, more recently a complementary instrument to the BMD has been developed called the *Value Proposition Canvas (VPC).* This wants to further elaborate and seek to match two key points of the BMC - Value Proposition (Value Map) and Customer Segments (Customer Profile).
The former is broken down into products and services offered, pain relievers and gain creators to the consumer. While the second (Customer Profile) seeks to target the consumers by identifying their jobs (Customer Jobs), Gains that they want to benefit the consumer, and Pains (risks,

obstacles) that they want to avoid or solve. When the Value Map meets the Customer Profile, the so-called Fit between what a business offers and what the consumer wants is achieved. This is the condition number one for creating a successful value proposition and thus a winning business model (*Pritchett, 2014; Lewandowski, 2016*).

Although several expert researchers and practitioners including *Renswoude et al., 2015* states that *"100% circular business models do not exist (yet)"* (*Renswoude et al., 2015*). Over the past decade, various design methods and tools have been developed in an attempt to transform various business models into future-proof and more circular ones. All, such as the 7-P model proposed by *Scott, 2015*, mainly involve getting informed about CE, arranging to implement *ReSOLVE* principles, and enabling the adoption of CE through the creation of dedicated teams and departments, as well as managing change effectively (*Scott, 2015*).

On the other hand, there are other useful tools for estimating the environmental impact of a specific business model on the environment. The most important of these is the *Life Cycle Assessment (LCA).* According to the definition proposed by SETAC (Society of Environmental Toxicology and Chemistry), *it is a methodology that assesses the environmental loads associated with a product, process or activity by identifying and quantifying material and energy consumption and emissions into the environment* (*SETAC Code of Conduct*).

The methodology is based on a systematic approach defined as "from cradle to grave" which therefore analyses the product, process or service at every stage of its life: from extraction and transformation of raw materials, through production, transport and use, to recycling or disposal. Through an LCA study, it is therefore possible to identify the most critical stages for environmental risk, the parties who will have to deal with them (stakeholders, producers, users, etc..) and the information needed to implement measures for improvement within a determined system boundaries (i.e. including or excluding stages of the product's life process and potential direct or indirect emissions and pollutants caused by it).

Particularly in the industrial field, this tool allows companies to keep pragmatically analysing the characteristics of their operations with a view to their compliance with legal regulations and reference standards. It is therefore a suitable tool for pursuing sustainable development initiatives, allowing the evaluation of the potential environmental impacts associated with the introduction of technological or process innovations in a production cycle, with a view to an overall process balance (*Bjørnbet & Vildåsen, 2021*).

Other studies, such as *Parlikad et al., 2003 et al.* and *Scott, 2015* emphasise the notion that the good use of IT and data management systems and services are essential for the application of

circular economy principles. In fact, IT can be crucial for tracking products, components and materials to ensure an efficient, waste-free production chain; also supporting a reverse logistics system that enables optimisation of recycling patterns (*Lewandowski, 2016)*.
In one hand, in the literature has been also reported that validating and applying circular business models often presents greater business risks than traditional linear models (*Linder & Williander, 2017).* On the other hand, many other investigations affirm that circularity often leads to higher revenues due to a wider spectrum of possible profits, greater business model resilience (less dependence on external partners) and reputational and financial value due to its propensity for sustainability (*Laubascher & Marinelli, 2014; Ellen MacArthur Foundation, 2013; Besch, 2005; Heese et al., 2005*).

In fact, different types of business model (BM) transformation towards sustainability can occur. That is, from the mildest to the most revolutionary: BM adjustment (marginal changes to integrate some EC concept into the company's BM), BM innovation (when a large part of the BM is transformed), and finally BM redesign (when there is a complete rethinking of the organisation and implementation of the BM elements that often involves a radical change in the value proposition (*Gauthier & Gilomen, 2016*)).

Therefore, the elements of the business model adapted to the values of the circular economy would be:

1) **Circular Value Proposition** enabling the extension of the life cycle of products through incentives for their retention, repair, resale (second-hand) and redistribution. This is only possible if upstream there is a re-thinking of their design; that is, to design them modularly to stimulate their reuse, recycling, sorting and collection (*Planing, 2014; Lacy et al., 2014; Bakker et al., 2014*). In this case, companies in order to still keep their revenues high would offer their customers other complementary services, e.g. leasing, renting or pay-per-service products for a particular customer segment. In extreme and more radical cases, the new circular value proposition (or part of it) could lead to a shift from a traditional, concrete product/service into a virtual good, such as digital clothes or accessories (e.g. trivially digitalising clothes labels reducing waste and use of resources) (*Ellen MacArthur Foundation, 2015; Renswoude et al., 2015*).

2) **Key Activities** focused on improving the performance of the production process from cradle to grave. Trying to keep products 100% in the closed material loop, so as to reduce waste. This requires a continuous and assiduous process of monitoring and optimising the value chain, removing, replacing and/or digitalising environmentally costly processes (*Scott, 2015*).

3) **Key Resources** employed should be more environmentally friendly or that restore natural capital. Using renewable energy, saving water, adopting better performing materials, digitalising products/services when possible, and promoting circularity of products (ideally in closed-loops) (*Renswoude et al., 2015*).

4) **Key Partners** such as suppliers, policy makers and research institutes that collaborate throughout the production chain allow products to be circulated in closed-loops (*Renswoude et al., 2015*). Without collaborative relationships, achieving an effective circular business model is almost impossible (*Saebi & Foss, 2015*).

5) **Customer Relationship** in a transparent and clear manner regarding production processes and recycling strategies allows waste to be reduced. Indeed, creating community-based businesses opens up the possibility of educating the customer, who will consequently trust the brand more and demand increasingly environmentally friendly products (and if well instructed will probably be inclined to pay an higher price) (*Lacy et al., 2014*).

6) **Channels** used by companies should be able to communicate and sell the new virtualised value proposition or in the case of a non-virtualised value proposition at least be virtual themselves (online shop, web advertising, social media, emails, video conferences) (*Ellen MacArthur Foundation, 2015).*

7) **Customer Segments** closely related to the value proposition identifies the best customer fit for it. Depending on the channels used or the value proposition chosen, different consumer segments will be identified (*Lewandowski, 2016).*

8) **Cost Structure** reflects economic changes made for the adoption of new CBMs. Often additional and specific evaluation criteria have to be added whenever changes are

introduced to the business model to implement its circularity (*Laubascher & Marinelli, 2014*).

9) **Revenue Streams** makes the value proposition of the business model viable or not. If the company does not make money, it will hardly continue to produce and thrive. In CBM, there are several strategies to make ends meet, such as: firstly, charging for the entire product/service upon sale (often unsuitable for CBM implementation); secondly, through a subscription to rent an asset (in order to reduce over production); thirdly, paying per use (paying once to use a good or service); and lastly, payment based on performance. Finally, profit generation may also come from recycling the product or part of it in a (preferably closed) recycling system (*Renswoude et al., 2015*).

In addition, in order to implement the *ReSOLVE* framework within the circular business model, in the most recent literature two more blocks are added to the classical BM, namely "Take-back system" and "Adoption factors" (*Ellen MacArthur Foundation, 2015*; *Lacy et al., 2014*):

10) **Take-back system** allowing the product to be reintegrated into the production cycle. The management of an efficient reverse logistic system includes incentives for the return, re-utilisation and collection of used products. This may involve new various partners, channels and customer relations (*Ellen MacArthur Foundation, 2014; Renswoude et al., 2015*).

11) **Adoption Factors** enabling the adaptation of circular economy principles into the new circular business model. They can be both internal and external to the company. The internal ones involve the development of human resources and corporate culture, as well as the use and application of various change management tools and risk assessment models. External ones, on the other hand, include support from outside the company to solve possible technology, political, socio-cultural or economic issues. IT and data management tech often provide support in this regard (*Scott, 2015; Laubascher & Marinelli, 2014*).

Thus, in order to achieve the 17 SDGs and, in particular, reduce the environmental impact of the textile and fashion industry, a systemic approach is strictly necessary. In addition, the involvement and collaboration of all major stakeholders in the value chain is essential in order to implement and enable the use of the latest and most innovative production, management and recycling tools and technologies to the broadest possible market segment. Therefore, business models and circular strategies must be supported by continuous research and development of effective technologies capable of closing the loop and reintegrating waste from the end-of-life phase of a product into resources for the manufacture of the next one.

2.4 Open- and Closed loop recycling of textile and apparel products

In order to find an holistic solution for the effective implementation of a circular system in the textile and fashion industry, efficient communication throughout the supply chain concerning how textile waste should be collected and disposed is imperative; as well as the development of efficient sorting and recycling technologies (*Koszewska, 2018*). In fact, reusing and recycling textiles significantly reduces the production of new virgin fibers and is deeply more sustainable compared to incineration and landfilling (*Juanga-Labayen et al., 2022)* which is where 80% of textiles and clothing materials end up today (*Lewis, 2015; Danigelis, 2020*).

Textile recycling can be classified in several ways, one of the most common distinguishes between: mechanical, chemical and biological recycling techniques. The first one mechanically breaks down textile waste for other purposes such as insulation materials for construction, decoration, and other uses related to agriculture and gardening. While the chemical recycling process depolymerises (in the case of polyester) or dissolves (in the case of cotton and viscose) the polymers of textile waste in order to reintegrate these fibers into the manufacturing chain of other textiles or to produce other goods such as bioethanol in the case of cellulose fibers (*Juanga-Labayen et al., 2022).* Finally, the last uses biological processes such as anaerobic digestion, fermentation and composting, which under certain conditions respectively generate resources such as methane, ethanol and soil supplement from cotton waste (*Rai et al., 2014; Gholamzad et al., 2014; Hamawand et al., 2016).*

Moreover, the fabric recycling pathway can also be distinguished according to the processes used and the desired type and quality of the final result. In other words, fabric recycling is when the whole fabric is regenerated or reused in new products while preserving the original fibers. Whilst polymer or oligomer recycling leads to the fiber disassembly into its protein components thereby preserving the monomers (*Sandin & Peters, 2018*). In addition, another way of sorting textile recycling operations is according to the value and type of product it will become after this process. Hence, if the resulting product after the recycling phase acquires a superior quality or value than the original product, the process is called "upcycling"; whereas if the value of the resulting product is lower, it is called "downcycling" (*Juanga-Labayen et al., 2022)*.

Finally, there are two other different ways to differentiate the recycling processes, called respectively: "Open-loop recycling" and "Closed-loop recycling".

I. **Open-loop recycling (OLR):** i.e. when at the end of a product's life cycle it is disassembled or degraded for being used in another product system, often unrelated to the first. Usually, the second product is of inferior quality and cannot be recycled at the end of its life's cycle. For this reason, OLR delays the end-of-life phase of the initial product and decreases the consumption and need to generate new virgin textile fiber (*Payne, 2015)*.
This kind of recycling process in the case of garments and textile materials includes:

- <u>Industrial waste:</u> as scraps of textile material discarded during the production process

- <u>Post-consumer waste:</u> generally consisting of entire garments that have been ruined or are no longer used.

- <u>Post-consumer PET bottles:</u> that can be recycled to generate PET fibers (RPETs).

In fact, several methods have been developed over the years to regenerate fibers from these different types of textile waste. Typically, these are mechanical processes in which fabrics made from natural (cotton or wool) and synthetic (polyester or nylon) fibers are collected, sorted and removed from hypothetical metal parts and then shredded into small pieces by a rotary blade. The fibers are then separated in a procedure called "picking", "pulling" or "tearing" in which they are slowly stripped from the fabric.

Furthermore, another excellent example of OLR is that provided by PET plastic bottles (non-biodegradable), which since the 1970s can be recycled into PET flakes, re-spun into new fibers (often of slightly lower quality) and then woven or knitted into new garments (*Langley & Kim, 2006; Payne, 2015*). The literature is plenty of LCA studies confirming the benefits of using recycled PET bottles to produce clothes compared to employing virgin PET in terms of energy consumption, emissions and eutrophication (*Shen et al., 2010)*.

As a matter of fact, the use of such recycled fibers depends very much on the quality of the feedstock used. In fact, industrial waste is the easiest to process because it is often of the same colour and material, without being adorned or over-treated chemically. In this case, indeed, the fibers obtained after OLR are shorter than the original ones, but still of sufficient good quality and length to be used as material for apparel. However, in general, recycled fibers are often blended with pure virgin fibers if they have to be reused for garments manufacturing. If, on the other hand, the fibers are not of adequate quality, the re-used fibers will be employed as insulation material for buildings, for cleaning cloths, nonwoven textiles, as fibers for the paper industry, carpet underlay, and finally for gardening or agricultural uses (*Payne, 2015)*.

Several brands already started to use OLR in the 1990s, and in particular to integrate RPET in the production of certain product lines. Among the first was the brand Patagonia (*Brown & Wilmanns, 1997*) to incorporate recycled polyester into their Capilene® hard shells, boardshorts, fleece and baselayers; and in general to reduce the use of virgin polyester in their production line as much as possible. They have planned indeed, for the spring 2022 season, to make 88% of their polyester garments using RPET. By doing so, they claim to have avoided the emission of over 5.2 million pounds of CO_2e into the atmosphere (*Patagonia website, 2022).* Several other fashion brands have used and still use RPET in apparel, including North Sails, Adidas, H&M, Max Mara, Armani and many others (*Payne, 2015)*.

II. **Closed-loop recycling (CLR):** is called the recycling path of pre- or post-consumer textile waste that leads to the manufacture of a product similar to the original. So this, or part of it, goes back into the same production chain after its use (*Juanga-Labayen et al., 2022*).
There are two types of CLR: Biological and Technical.
Biological CLR refers to natural fibers such as cotton or wool that at the end of their life cycle naturally degrade in the soil returning as nutrients into the biosphere. While technical CLR refers to non-biodegradable products. Indeed, the textile industry produce also a large quantities of synthetic fibers such as polyester, nylon and acrylic that are often bounded with natural fibers (such as cotton-polyester or viscose-polyester) and these are referred to as "monster hybrids" because they are virtually impossible to separate and recycle (*McDonough & Braungart, 2002*). Currently, there are multiple methods on the market for the CLR of synthetic fibers such as PET or nylon in which the fibers polymers are disassembled and then re-polymerised before being spun to generate new material. Although this process often results in a lower quality fiber for each recycling cycle, *Teijin Textile* in

Japan has developed a system to produce RPET of the same standard as virgin fiber. According to their partner *Patagonia*, this leads to significant savings in energy, waste and emissions even when the transport of the goods between US (*Patagonia*) and Japan (*Teijin*) is taken into account within the LCAs (*Patagonia, 2009*). In another LCA carried out for the retailer *Espirit*, it was shown that a recycled cotton t-shirt saves up to 75% water compared to a virgin fiber T-shirt (*Espirit, 2014*).

In any case, the reuse of second-hand clothes, upcycling and closed-loop recycling are today the best recycling routes that minimise the environmental impact of the textile and clothing industry by maximising the use of resources and reducing waste of raw materials, water and energy the most (*Chavan, 2014*). According to *Woolridge et al., 2006* in fact, approximately 65 kWk and 95 kWk would be saved for each kg of cotton replaced by second-hand clothes or made of RPET respectively (*Woolridge et al., 2006).*

Finally, today there are other biotech alternatives available to generate added value from textile waste (*Juanga-Labayen et al., 2022*), such as:

- Anaerobic digestion for biogas production. Indeed different studies have demonstrated that cotton waste which is characterized by an high amount of cellulose (around 50%) can be used to generate methane-rich biogas (*Rai et al., 2014; Isci & Demirer, 2007*).

- Fermentation for ethanol production up to a maximum yield of 70% (*Gholamzad et al., 2014*).

- Composting cotton waste into valuable soil supplement employing natural microorganism. This methods allow to reduce organic waste volume up to 50% and generating rich soil (*Hamawand et al., 2016*). Recent studies have also demonstrated that the resulting compost is particularly suitable as substrate for the cultivation of edible oyster mushrooms (Oh et al., 2004; *Phuong, 2016*).

- Thermal recovery i.e. generating thermal energy by incinerating non-recyclable textile waste as an alternative to landfilling. However, in order to maintain constant combustion standards and temperatures, this type of waste often has to be mixed with paper and cardboard residue (*Ryu et al., 2007*).

- <u>Conversion into construction or insulation materials for buildings</u>. Indeed waste from non-recyclable textile fibers can be mixed with composite concrete materials reinforcing them by functioning as a solid matrix. This creates the textile reinforced concrete (TRC) widely used in the construction industry. In addition, textile waste can be rewrapped to form thermal insulation and soundproofing materials to fill gaps between walls (*Pichardo et al., 2018; Williams Portal et al., 2015; Alexander & Shashikala, 2020*).

Fig. 2 shows an overview of the various types of reuse and recycling processes generally employed nowadays.

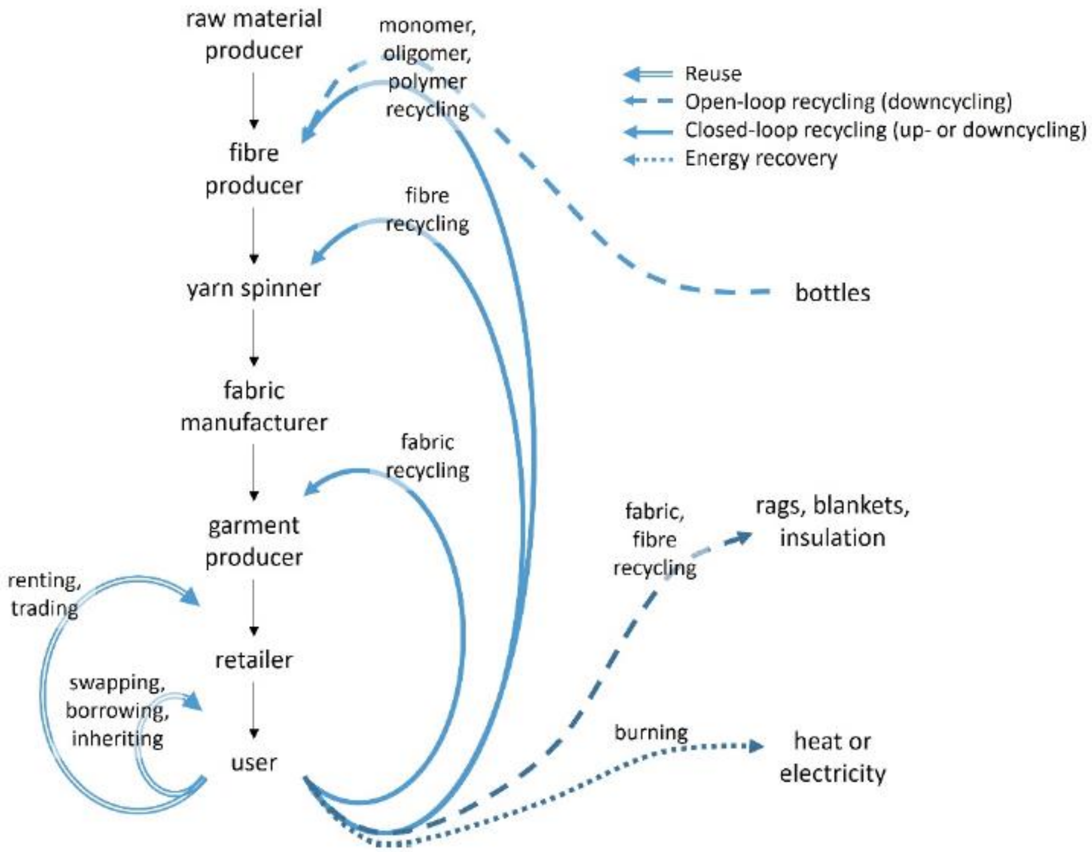

Figure 2: *Recycling and reuse path and classification of textile products - Retrieved from: Sandin & Peters, 2018.*

2.5 Deliverables of innovative strategies for emerging fashion start-ups

Finding consistent data in the literature on advisable strategies for fashion/textile start-ups wishing to circularise their business models has been challenging. However, from multinational fashion brands and other isolated innovative realities, it is possible to encapsulate in several categories the improvements that can be replicated in small companies to facilitate the transition towards the CE (*Vinante et al., 2019*). Some of these relate to different building blocks of the *ReSOLVE* framework and can be subdivided by:

I. **Material Sourcing:** Generation of an open and diversified market characterised by transparency and synergy between companies is of paramount importance in order to introduce CBMs. Focusing the production, distribution and marketing strategies of products and services on the energy efficiency and environmental impact of processes accurately assessed through LCAs. By choosing the most sustainable and easily recyclable materials, promoting functional recycling and upcycling. This requires legislative support that taxes technologies with negative externalities and provides subsidies and incentives towards more sustainable initiatives.

II. **Design:** Product design plays a crucial role in the transition to circular business models. It must ensure modularity of its components, use fewer materials, eliminate toxic chemicals and focus on its environmental consequences. Allowing the easy disassembly and collection of products in order to facilitate their repair and recycling (preferably CLR) by maximising their life cycle extension.

III. **Manufacturing:** The manufacturing process must be energy efficient, ensuring the greatest amount of economic value is generated per input of material used. Furthermore, the production technology must be transparent and scalable, and IT tools for managing resources must be able to constantly monitor and improve the fabrication system.

IV. **Distribution & Sales:** The (re-)distribution and (re-)sale system are important to extend the product life-cycle and to be reused. Furthermore, efficient packaging solutions and sales strategies to reach buyers must respect the environment and have zero or (even better) negative impact.

V. **Consumption & Use:** The relationship between producer and consumer is of paramount importance to achieve a sustainable fashion industry system. Community and stakeholders involvement should be fostered in order to create sharing platforms and systems that enable repair and exchange of products as well as replacement information. Also product (eco-) labelling should provide the consumer with essential information on the origin of raw materials and the comprehensive impact of that garment on the environment, leading to socially responsible consumption. Finally, the dematerialisation and digitisation of physical products and services where possible would result in a significant reduction in consumption and waste of natural resources.

VI. **Collection & Disposal:** A functional garment collection and disposal system is crucial to close the loop and regenerate value from waste. Therefore, environmental policies that extend producer responsibility for a product even after the post-consumer stage and recycling incentives are critical. As well as the implementation of reverse logistics systems that bring back to the manufacturer garments that have reached the end of their life cycle are necessary to guarantee a constant inflow of materials for remanufacturing.

VII. **Recycling & Recovery:** At the end of their life cycle, products must be capable of being reintegrated into a cascade process for new product development. Preferably in closed-loop recycling or upcycling systems. If these alternatives are not viable, the energy contained in the materials can be recovered through combustion, gasification, pyrolysis, anaerobic digestion or reconversion into building materials, avoiding landfilling.

VIII. **Remanufacture:** Refurbishment and remanufacture of damaged product components should be encouraged. Therefore, in order to maintain revenue by selling fewer products, companies must be able to sell after-sale complementary services that boost business, such as maintenance, rental, customisation and garment reconditioning solutions..

IX. **Circular inputs:** The inputs of materials and resources used must be easily renewed, long-lasting and environmentally friendly (*Kalmykova, 2018*).

Beyond that, more specifically, several emerging innovative companies and start-ups are trying to advance new frontiers in the development of cutting-edge sustainable materials and production techniques for the textile and fashion industry; often in collaboration with established multinational brands. An overview of some of the most promising innovations currently available on the market is hereby provided *(Tab. 2)* :

Brand	Sector	Technology	Reference
Adidas	Sporting Goods Manufacturing	Recently collaborated with Bolth Thread to produce trainers in Mylo - a leather-like material derived from mycelium; and with Spinnova to produce a hoodie made of the sustainable material SPINNOVA&reg.	AdidasxMylo AdidasxSpinnova
AlgiKnit	Biotechnology	Uses Kelp seaweed to produce materials for fashion.	https://www.algiknit.com/hello
AMsilk	Biotechnology	Supplies vegan silk biopolymers and offers its innovative range of high-performance Biosteel® fibres for textiles and industrial applications worldwide and has announced collaborations and partnerships with world leading brands like Adidas and Airbus.	https://www.amsilk.com/
Ananas Anam Ltd	Textiles	Piñatex® by Ananas Anam is a sustainable natural textile made from pineapple leaf fiber. (Recently collaborated with Nike to produce vegan cork snickers).	https://www.ananas-anam.com/
Be Green Tannery	Leather tannery	Supplies leather and sustainable dyeing processes for environmentally friendly fashion brands.	https://begreentannery.com/
Biofabricate LLC	Design Services	Through the use of biotechnology, it produces innovative and sustainable biomaterials for various sectors. It also offers a global network of start-ups, brands and investors that provides strategic advisory services to move towards biomaterials and corporate sustainability.	https://www.biofabricate.co/
Bolt Threads	Biotechnology	The biotechnology company Bolt Threads has brought together some new and existing partners, including Stella McCartney, Kering, Lululemon and Adidas to create a consortium that will explore the company's use of its mushroom-based leather substitute in products.	https://boltthreads.com/ BolthThreadsPartners

CELLINK	Biotechnology	Bio-convergence company and global provider of technologies, products and services to create, understand and master biology. Focusing on the areas of bioprinting, biosciences and industrial solutions, developing and commercialising innovative technologies that enable the implementation of 3D cell cultivation methods, accurate drug screening and the printing of human tissues and organs for medical, pharmaceutical and cosmetic purposes.	https://www.cellink.com/
Colorfix	Textiles	Developed an innovative dyeing process to help the textile industry significantly reduce its environmental impact in a cost-effective manner. Using synthetic biology, they produce, deposit and fix dyes biologically, avoiding the use of harmful chemicals and reducing resource use and waste generation.	https://colorifix.com/
Covalent	Apparel & Fashion	Carbon-negative eyewear and accessories, made with AirCarbon®.	https://covalentfashion.com/
DAN*NA	Biotechnology	DAN*NA produce high-tech biomaterials and bioplastics for sustainable future technologies.	https://artificialnature.com/
DESSERTO	Apparel & Fashion	Sustainable plant based vegan leather made of Cactus.	https://desserto.com.mx/home
ECCO Leather B.V.	Apparel & Fashion	Creates innovative, cutting-edge leathers for different brands in the fashion industry.	https://eccoleather.com/
ECOALF	Apparel & Fashion	Conscious clothing brand that aims to realise innovation in recycled clothing - pioneers in sustainable fashion.	https://ecoalf.com/en
Ecovative Design	Biotechnology	Exploit mycelium to grow a variety of products: from leather-like fabrics to sustainable packaging to high-performance foams for clothing and beauty. (Recently collaborated in the Fashion for Good project with Bestseller, Pangaia, PVH Corp. and Vivobarefoot)	https://www.ecovative.com/
Fruitleather Rotterdam	Biotechnology	Developed a process that converts left-over fruit into leather-like material.	https://fruitleather.nl/
FTL – Future Tech Lab	Apparel & Fashion	Platform aimed at transforming industries, accelerating and empowering an innovative and sustainable future.	https://www.ftl.ltd/

Hide Biotech	Biotechnology	Start-up developing innovative sustainable biomaterials inspired by leather.	http://hidebiotech.com
Infinited Fiber Company	Renewable Energy Semiconductor Manufacturing	Tansforms materials that would otherwise be landfilled or burnt into textile material – Infinna™, a premium textile fiber that reduces the world's reliance on virgin resources. (Recently partnered with H&M Group, BESTSELLER, PVH Corp., Wrangler, Patagonia and Suominen).	https://infinitedfiber.com/
Living Ink Technologies	Biotechnology	Transforms algae into carbon negative, renewable, safe pigments and ink products. (Recently collaborated on the production of several Nike, Marmot, American Eagle, Patagonia and Vollebak products).	https://livingink.co/
Malai Biomaterials Design pvt. ltd.	Design	Creates bacterial cellulose from coconut water.	https://malai.eco/
Mango Materials	Biotechnology	Uses waste biogas (methane) to produce PHA powder that is converted into a variety of eco-friendly, plastic products such as cosmetic packaging and a polyester replacement for textiles.	https://www.mangomaterials.com/
Miomojo	Apparel & Fashion	Designs sustainable garments using vegan products and processes.	https://www.miomojo.com/en/
Modern Meadow	Biotechnology	Modern Meadow's proprietary Bio-Alloy™ and Bio-F@rm™ technology platforms exploit the unique properties of tuned proteins to develop superior biomaterials and sustainable products free of petrochemicals and animal products.	https://www.modernmeadow.com/
Modern Synthesis	Retail / Apparel & Fashion	It produces biomaterials for the fashion industry by combining biology, material science and design.	https://modern-synthesis.com/
MYCL | Mycotech Lab	Biotechnology	Providing high performance and sustainable materials through biotechnology while empowering local communities.	https://mycl.bio/
MycoTEX	Apparel & Fashion	Developed NEFFA: 3D manufacturing/ bioprinting methods to create custom-fit products out of sustainable, vegan textiles made from mycelium.	https://www.mycotex.nl/
MycoWorks	Biotechnology	Develops biomaterials inspired by nature and using mycelium technology, Fine Mycelium™. Moreover, their first product, Reishi™, offers fashion companies an option for leather that is neither animal nor plastic,	https://www.mycoworks.com/ https://www.mycoworks.hermes

		but without compromising quality and aesthetics. (Recently collaborated with Hermes to create a bag made of Fine Mycelium™).	
Mylium BV	Textiles	Fabrics made with mycelium technology.	https://www.mylium.nl/
Nat-2™	Apparel & Fashion	Producing engineered high-end sustainable sneakers and footwear.	https://www.nat-2.eu/
Nature Coatings Inc.	Chemical Manufacturing	Transforms wood waste into high-performing black pigments.	https://naturecoatingsinc.com/
NatureWorks	Plastics	Fabricates biomaterials using plants to transform greenhouse gases into Ingeo™ PLA bioploymer.	https://www.natureworksllc.com/
Orange Fiber s.r.l.	Textiles	Produces sustainable fabrics from citrus juice by-products. (Recently partnered with Ferragamo and H&M).	https://orangefiber.it/it/
Pangaia	Retail / Apparel & Fashion	Manufactures garments made from biomaterials, recycled fibers and innovative dyeing techniques striving for 100% sustainable products.	https://pangaia.com/
Patagonia	Retail / Apparel & Fashion	Outdoor clothing company recognised internationally for its commitment to product quality and environmental activism, it donates 1% of sales annually, contributing over $100 million in grants and in-kind donations since 1985. (Recently collaborated with several innovative companies such as Living Ink Technologies, Infinited Fiber Company, Teijin Textile).	https://eu.patagonia.com/it/it/home/
PelCork	Apparel & Fashion	Design products made with natural and organic materials such as cork and skin cork.	https://www.pelcor.pt/
PILI	Biotechnology	Focused on the biofabrication of a wide range of sustainable colours produced by microorganisms.	https://www.pili.bio/
Polybion	Biotechnology	Grows high-performance & circular carbon sourced (CCS) bio-assembled textiles.	www.polybion.mx
Ragnarok Clothing	Retail/ Apparel & Fashion	Fashion brand which seeks to reconnect the consumer with the planet by promoting sustainable products and practices.	https://ragnarok-clothing.com/
Spiber Inc.	Biotechnology	Develops microbially-fermented Brewed Protein™ materials to help build a more sustainable society. (Collaborated with Goldwin and North Face in the past to produce sweater and jacket respectively. Recent partnership with Pangaia to produce hoodie	https://spiber.inc/en/

		made from Brewed Protein™ fibre and organic cotton).	
Spinnova	Research/ Textile	Develops textile fiber directly out of FSC-certified wood and waste streams without dissolving or other harmful chemical processes. (Recently collaborated with Adidas to produce a hoodie made of the sustainable material SPINNOVA&reg).	https://spinnova.com/
Teijin Frontier Co., Ltd.	Chemical Manufacturing	Developed a system to produce RPET of the same standard as virgin fiber.	https://www.teijin.com/
Vegea	Biotechnology	Develops sustainable & animal friendly biomaterials for fashion, furniture, automotive and packaging. (Recently partnered with H&M, & Other Stories, Serapian, Le Coq Sportif and Calvin Klein).	https://www.vegeacompany.com/ https://www.vegeacompany.com/news/
Veja	Apparel & Fashion	Create sustainable sneakers by merging social projects, ecological materials and design. Using organic cotton and Amazonian rubber directly from producer associations based in Brazil and Peru. But also innovative materials such as RPET bottles.	https://www.veja-store.com/
Villabank	Retail / Apparel & Fashion	Employs science and technology to create futuristic and sustainable clothing.	https://www.vollebak.com/
Zymergen	Biotechnology	Manufactures innovative molecules, microorganisms and biomaterials for various purposes and sectors.	https://www.zymergen.com/

***Table 2**: Overview of some of the most innovative and promising companies currently offering solutions to reduce the environmental impact of the textile and fashion industry (in alphabetical order).*

The above-mentioned companies and start-ups are just some of the novelties on the market; which are trying to lead the textile and fashion industry towards the right direction. Interestingly, as it emerges in *Tab. 2*, many of them frequently collaborate with major, established multinational brands. In this way they manage to successfully leverage their financial and productive capacities, thus achieving a significant impact on a large scale and reaching a broad consumer audience.

3. Conclusions

The steady growth of the world population, the "fast fashion" phenomenon, and the improvement of universal living standards has caused a dramatic increase in the production of textiles and clothes, generating alarming amounts of unsold garments and fabrics waste worldwide.

To solve this global alarming threat, the CE principles should be adopted throughout the entire value production and distribution chain of textile and fashion companies in order to implement long-term economic and environmental sustainability. Applying the 3 R's and the ReSOLVE framework at every level of the business system and extending the product's life span; as well as employing useful tools such as LCA, BMC and VCP to reduce waste, evaluate and determine which products/production methods need to be revised, replaced or (increasingly today) virtualized.

It is indeed the responsibility of companies to modularly design their products for easy disassembly and disposal. Using energy from renewable sources and opting for organic and sustainable materials and manufacturing processes. Effectively communicating to consumers how to dispose of them correctly thus extending producer responsibility. However, in order to move from linear to circular business models, a holistic and multidisciplinary approach is crucial; involving the collaboration of the major stakeholders (industries, suppliers, governments, policymakers and consumers) that promotes a shared and synergistic economy across the entire value chain to achieve the set targets and gain a systemic competitive advantage.

Furthermore, this research showed that the reuse and recycling of textile materials is evidently more sustainable than incineration and landfilling, thus avoiding the production of new virgin fiber (economically and environmentally costly). Moreover, in any case, the reuse and recycling of clothes - and thus the extension of their end-of-life phase - is more beneficial than their recycling nowadays. In addition, upcycling and closed-loop recycling of textile materials are preferable to their reintegration into the production of other, lower-quality products (open-loop recycling), but these technologies need to be further improved and facilitated also for small, emerging start-ups.

Finally, IT services and new digital tools for the efficient management of manufacturing operations are essential to reduce waste, emissions and to build a reverse logistics network that enables the circularity of the entire market system.

In conclusion, a growing number of new pioneering businesses developing and mastering high-quality sustainable biomaterials and production/ recycling processes are gaining ground. Often through collaboration with established multinational brands, they are succeeding in reducing research and development costs and scaling up their technologies, and thereby opening it up to an ever larger consumer segment. However, to achieve a viable global sustainability of the textile and fashion industries, these innovative realities need to be supported by financial incentives and a taxation systems which promote and facilitate the use and implementation of these new disruptive technologies. Last but not least, as revealed by the various examples provided in this literature review, cooperation between both small and large enterprises and open knowledge sharing is currently the most effective and fastest way to achieve sustainability within the sector. Gradually integrating circular business models, cutting-edge regenerative technologies and resource tracking and management systems also in small emerging fashion and textile start-ups. Thus achieving a responsible, synergetic and resilient economy.

Bibliography

1) Jacometti, V. (2019). Circular Economy and Waste in the Fashion Industry. *Laws*, *8*(4), 27. https://doi.org/10.3390/laws8040027

2) Koszewska, M. (2018). Circular Economy - Challenges for the Textile and Clothing Industry. *Autex Research Journal*. https://doi.org/10.1515/aut-2018-0023

3) Ellen Macarthur Foundation. (2017). A New Textile Economy: Redesigning Fashion's Future. Available online: https://ellenmacarthurfoundation.org/publications

4) McKinsey & Company. (2016). The circular economy: moving from theory to practice. *Annales d'oto-Laryngologie et de Chirurgie Cervico Faciale : Bulletin de La Société d'oto-Laryngologie Des Hôpitaux de Paris*.

5) Planing, P. (2014). Business Model Innovation in a Circular Economy Reasons for Non-Acceptance of Circular Business Models. *Open Journal of Business Model Innovation*, 1–11.

6) Ellen MacArthur, F. (2015). Delivering the Circular Economy: A Toolkit for Policymakers. *Delivering the Circular Economy: A Toolkit for Policymakers*, 177.

7) Prieto-Sandoval, V., Jaca, C., & Ormazabal, M. (2018). Towards a consensus on the circular economy. *Journal of Cleaner Production*, *179*, 605–615. https://doi.org/10.1016/j.jclepro.2017.12.224

8) BOF & McKinsey (2019). The state of Fashion Report 2019. Available online: https://www.businessoffashion.com/articles/intelligence/the-state-of-fashion-2019

9) Gazzola, P., Pavione, E., Pezzetti, R., & Grechi, D. (2020). Trends in the fashion industry. The perception of sustainability and circular economy: A gender/generation quantitative approach. *Sustainability (Switzerland)*, *12*(7), 1–19. https://doi.org/10.3390/su12072809

10) Singh, G. (2017). Fast Fashion Has Changed the Industry and the Economy - Foundation for Economic Education. Retrieved from https://fee.org/articles/fast-fashion-has-changed-the-industry-and-the-economy/

11) Anguelov, N. (2015). *The dirty side of the garment industry: Fast fashion and its negative impact on environment and society*. *The Dirty Side of the Garment Industry: Fast Fashion and Its Negative Impact on Environment and Society* (pp. 1–220). Taylor and Francis Inc. https://doi.org/10.1201/b18902

12) Sull, D., & Turconi, S. (2008). Fast fashion lessons. Business Strategy Review, 19(2), 4–11 (pag 6). https://doi.org/10.1111/j.1467-8616.2008.00527.x

13) McKinsey&Co, Remy, N., Speelman, E., & Swartz, S. (2016). Style that's sustainable : A new fast-fashion formula. *Sustainability & Resource Productivity Mckinsey & Company*.

14) Bhardwaj, V., & Fairhurst, A. (2010). Fast fashion: Response to changes in the fashion industry. *International Review of Retail, Distribution and Consumer Research*, *20*(1), 165–173. https://doi.org/10.1080/09593960903498300

15) Juanga-Labayen, J. P., Labayen, I. v., & Yuan, Q. (2022). A Review on Textile Recycling Practices and Challenges. *Textiles*, *2*(1). https://doi.org/10.3390/textiles2010010

16) Textile Exchange. Preferred Fiber & Materials, Market Report. 2020. Available online: https://textileexchange.org/wp-content/uploads/2020/06/Textile-Exchange_Preferred-Fiber-Material-Market-Report_2020.pdf (accessed on May 2022)

17) Zhang, M., Kong, X. X., & Ramu, S. C. (2016). The transformation of the clothing industry in China. Asia Pacific Business Review, 22(1), 86–109. https://doi.org/10.1080/13602381.2014.990204

18) Danigelis, A. (2020). Retailers Bank on Environmentally-Friendly Clothing for Increased Sales. *Environmental Leader*, *100*.

19) Lewis, T. (2015). Apparel disposal and reuse. In *Sustainable Apparel: Production, Processing and Recycling*. https://doi.org/10.1016/B978-1-78242-339-3.00010-8

20) Ellen Macarthur Foundation. (2013). Ellen Macarthur Foundation Towards a Circular Economy Vol 1: an economic and business rationale for an accelerated transition. In *Ellen MacArthur Foundation*.

21) Chesbrough, H.; Rosenbloom, R.S. The role of business model in capturing value from innovation: Evidence from Xerox Corporation's technology spin-off companies. 2002

22) Peeples, J. (2008). The politics of the Earth: Environmental discourses. *Politics and the Life Sciences : The Journal of the Association for Politics and the Life Sciences*, *27*(2).

23) Claiborne, R. (1972). The Closing Circle: Nature, Man and Technology. *Hospital Practice*, *7*(2). https://doi.org/10.1080/21548331.1972.11706151

24) Lewandowski, M. (2016). *sustainability Designing the Business Models for Circular Economy-Towards the Conceptual Framework*. https://doi.org/10.3390/su8010043

25) Ellen MacArthur Foundation. (2015). Growth within: a circular economy vision for a competitive europe. *Ellen MacArthur Foundation*.

26) Foundation, E. M. (2014). Towards the Circular Economy: Vol. 1: Economic and business rationale for an accelerated transition. *Ellen MacArthur Foundation*, *1*.

27) Johnson, E. A. J. (2012). Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers - By Alexander Osterwalder and Yves Pigneur. *Journal of Product Innovation Management*, *29*(6).

28) Osterwalder, A., Pigneur, Y., & Tucci, C. L. (2005). Clarifying Business Models: Origins, Present, and Future of the Concept. *Communications of the Association for Information Systems*, *16*. https://doi.org/10.17705/1cais.01601

29) Barquet, A. P. B., de Oliveira, M. G., Amigo, C. R., Cunha, V. P., & Rozenfeld, H. (2013). Employing the business model concept to support the adoption of product-service systems (PSS). *Industrial Marketing Management*, *42*(5). https://doi.org/10.1016/j.indmarman.2013.05.003

30) Devappa, R. K., Rakshit, S. K., & Dekker, R. F. H. (2015). Forest biorefinery: Potential of poplar phytochemicals as value-added co-products. In *Biotechnology Advances* (Vol. 33, Issue 6). https://doi.org/10.1016/j.biotechadv.2015.02.012

31) Cambero, C., & Sowlati, T. (2014). Assessment and optimization of forest biomass supply chains from economic, social and environmental perspectives - A review of literature. In *Renewable and Sustainable Energy Reviews* (Vol. 36). https://doi.org/10.1016/j.rser.2014.04.041

32) Pritchett, G. (2014). Value Proposition Design: How to Create Products and Services Customers Want. *Central European Business Review*, *3*(4). https://doi.org/10.18267/j.cebr.104

33) Renswoude, K. van, Wolde, A. ten, & Joustra, D. J. (2015). Circular Business Models Part 1: An introduction to IMSA's circular business model scan. *Circular Business Models: Developing a Sustainable Future*.

34) Scott, J.T. (2013). The Sustainable Business: A Practitioner's Guide to Achieving Long-Term Profitability and Competitiveness (1st ed.). Routledge. https://doi-org.proxy.library.uu.nl/10.4324/9781351276603

35) Bjørnbet, M. M., & Vildåsen, S. S. (2021). Life cycle assessment to ensure sustainability of circular business models in manufacturing. *Sustainability (Switzerland)*, *13*(19). https://doi.org/10.3390/su131911014

36) Parlikad, A. K., Mcfarlane, D., Fleisch, E., & Gross, S. V. (2003). The Role of Product Identity in, (June).

37) Besch, K. (2005). Product-service systems for office furniture: Barriers and opportunities on the European market. *Journal of Cleaner Production*, *13*(10–11). https://doi.org/10.1016/j.jclepro.2004.12.003

38) Heese, H. S., Cattani, K., Ferrer, G., Gilland, W., & Roth, A. v. (2005). Competitive advantage through take-back of used products. *European Journal of Operational Research*, *164*(1). https://doi.org/10.1016/j.ejor.2003.11.008

39) Linder, M., & Williander, M. (2017). Circular Business Model Innovation: Inherent Uncertainties. *Business Strategy and the Environment*, *26*(2). https://doi.org/10.1002/bse.1906

40) Gauthier, C., & Gilomen, B. (2016). Business Models for Sustainability: Energy Efficiency in Urban Districts. *Organization and Environment*, *29*(1). https://doi.org/10.1177/1086026615592931

41) Laubscher, M., & Marinelli, T. (2014). Integration of Circular Economy in Business. *Proceedings of the Conference: Going Green-Care Innovation*.

42) Lacy, P., Keeble, J., McNamara, R., Rutqvist, J., Haglund, T., Cui, M., Cooper, A., Pettersson, C., Eckerle, K., Buddemeier, P., Sharma, A., & Senior, T. (2014). Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth. In *Accenture Strategy*.

43) Bakker, C., Wang, F., Huisman, J., & den Hollander, M. (2014). Products that go round: Exploring product life extension through design. *Journal of Cleaner Production*, *69*. https://doi.org/10.1016/j.jclepro.2014.01.028

44) Saebi, T., & Foss, N. J. (2015). Business models for open innovation: Matching heterogeneous open innovation strategies with business model dimensions. *European Management Journal*, *33*(3). https://doi.org/10.1016/j.emj.2014.11.002

45) Sandin, G., & Peters, G. M. (2018). Environmental impact of textile reuse and recycling – A review. In *Journal of Cleaner Production* (Vol. 184). https://doi.org/10.1016/j.jclepro.2018.02.266

46) Payne, A. (2015). Open-and closed-loop recycling of textile and apparel products. In *Handbook of Life Cycle Assessment (LCA) of Textiles and Clothing*. https://doi.org/10.1016/B978-0-08-100169-1.00006-X

47) Langley, K. D., & Kim, Y. K. (2006). Manufacturing nonwovens and other products using recycled fibers containing spandex. In *Recycling in Textiles: A Volume in Woodhead Publishing Series in Textiles*. https://doi.org/10.1533/9781845691424.3.137

48) Shen, L., Worrell, E., & Patel, M. K. (2010). Resources , Conservation and Recycling Open-loop recycling : A LCA case study of PET bottle-to-fibre recycling. *"Resources, Conservation & Recycling," 55*(1).

49) Brown, M.S., Wilmanns, E. (1997).Quick and dirty environmental analysis for garments: what do we need to know? *The Journal of Sustainable Product Design 1, 28-35*.

50) Patagonia website (2022). https://eu.patagonia.com/gb/en/our-footprint/recycled-polyester.html (*Accessed on May 2022*)

51) Peterson, M. (2004). Cradle to Cradle: Remaking the Way We Make Things. *Journal of Macromarketing*, *24*(1). https://doi.org/10.1177/0276146704264148

52) Patagonia, 2009. Closing the Loop – a Report on Patagonia's Common Threads Garment Recycling Program. http://www.thecleanestline.com/2009/03/closing-the-loop-a-report-on-patagonias-common-threads-garment-recycling-program.html (*Accessed on May 2022*)

53) Espirit, 2014. Sustainability in Practice. https://www.esprit.com/en/company/sustainability/towards-circularity/our-strategy (*Accessed on May 2022*).

54) Chavan, R.B. Environmental Sustainability through Textile Recycling. (2014). *Journal of Textile Science & Engineering*, *s2*(01). https://doi.org/10.4172/2165-8064.s2-007

55) Woolridge, A. C., Ward, G. D., Phillips, P. S., Collins, M., & Gandy, S. (2006). Life cycle assessment for reuse/recycling of donated waste textiles compared to use of virgin material: An UK energy saving perspective. *Resources, Conservation and Recycling*, *46*(1). https://doi.org/10.1016/j.resconrec.2005.06.006

56) Raj, C. S., Arul, S., Sendilvelan, S., & Saravanan, C. G. (2014). Bio Gas from Textile Cotton Waste - An Alternate Fuel for Diesel Engines. *The Open Waste Management Journal*, *2*(1). https://doi.org/10.2174/1876400201002010001

57) Isci, A., & Demirer, G. N. (2007). Biogas production potential from cotton wastes. *Renewable Energy*, *32*(5). https://doi.org/10.1016/j.renene.2006.03.018

58) Gholamzad, E., Karimi, K., & Masoomi, M. (2014). Effective conversion of waste polyester-cotton textile to ethanol and recovery of polyester by alkaline pretreatment. *Chemical Engineering Journal*, *253*. https://doi.org/10.1016/j.cej.2014.04.109

59) Hamawand, I., Sandell, G., Pittaway, P., Chakrabarty, S., Yusaf, T., Chen, G., Seneweera, S., Al-Lwayzy, S., Bennett, J., & Hopf, J. (2016). Bioenergy from Cotton Industry Wastes: A review and potential. In *Renewable and Sustainable Energy Reviews* (Vol. 66). https://doi.org/10.1016/j.rser.2016.08.033

60) Oh, S.-J., Park, J.-S., Shin, P.-G., Yoo, Y.-B., & Jhune, C.-S. (2004). An Improved Compost Using Cotton Waste and Fermented Sawdust Substrate for Cultivation of Oyster Mushroom. *Mycobiology*, *32*(3). https://doi.org/10.4489/myco.2004.32.3.115

61) Phuong, T. T. (2016). Development of a new cotton waste composting technology for cultivation of oyster mushroom (pleurotus ostreatus). *ARPN Journal of Engineering and Applied Sciences*, *11*(21).

62) Ryu, C., Phan, A. N., Yang, Y. bin, Sharifi, V. N., & Swithenbank, J. (2007). Ignition and burning rates of segregated waste combustion in packed beds. *Waste Management*, *27*(6). https://doi.org/10.1016/j.wasman.2006.04.013

63) Pichardo, P. P., Martínez-Barrera, G., Martínez-López, M., Ureña-Núñez, F., & Ávila-Córdoba, L. I. (2018). Waste and Recycled Textiles as Reinforcements of Building Materials. In *Natural and Artificial Fiber-Reinforced Composites as Renewable Sources*. https://doi.org/10.5772/intechopen.70620

64) Williams Portal, N., Lundgren, K., Wallbaum, H., & Malaga, K. (2015). Sustainable Potential of Textile-Reinforced Concrete. *Journal of Materials in Civil Engineering*, *27*(7). https://doi.org/10.1061/(asce)mt.1943-5533.0001160

65) Alexander, A. E., & Shashikala, A. P. (2020). Sustainability of Construction with Textile Reinforced Concrete- A State of the Art. *IOP Conference Series: Materials Science and Engineering*, *936*(1). https://doi.org/10.1088/1757-899X/936/1/012006

66) Vinante, C., Gribaudo, E., Pavanetto, R., & Basso, D. (n.d.). 6 actions for the transition to Circular Economy – the REsolve framwork. *HBI Green Paper n. 16*, 3–5.

67) Kalmykova, Y., Sadagopan, M., & Rosado, L. (2018). Circular economy - From review of theories and practices to development of implementation tools. *Resources, Conservation and Recycling*, *135*, 190–201. https://doi.org/10.1016/j.resconrec.2017.10.034