A Life Cycle Thinking Approach to Analyse Sustainability in the Textile Industry: A Literature Review

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Abstract: The textile industry is one of the most important productive sectors worldwide, and everyone, to some extent, is involved in its value chain. For this reason, it is essential to be informed about its performance, problems and innovations. This paper presents the progress done in the transition towards sustainable production and consumption patterns. A literature review of the life cycle stages of textile products was carried out to identify initiatives and actions improving the performance. The findings show that transparency and traceability along the supply chain have been a fundamental piece in the transition. Besides, the creation of multi-stakeholders' clusters, seeking to improve social and environmental issues has been one of the most successful paths in this transition. However, a lack of training and skills along the life cycle stages and disconnection between products' design and strategies of recycling was found. For this reason, it is recommendable to generate an in-depth diagnosis of the textile industry at a global and regional level. As well, it is necessary to generate strategies and tools that facilitate this transition, mainly supporting SMEs (small- and medium-sized companies).

Keywords: environmental; social; impact; apparel; fashion; garment

1. Introduction

The policies and strategies developed in the last decade to promote sustainable development [1,2] have increased the pressure on the industrial sectors to protect the environment and show social responsibility [3]. Therefore, the evaluation of the sustainability performance of the industrial sectors becomes a key element to meet sustainability requirements effectively [4].

According to Brown et al. [5], "sustainability" is strongly context-related, i.e., its meaning depends on the context in which it is applied. In this line of thought, we argue that a useful definition must be established under a specific application. On the one hand, we frame the meaning of sustainability as the development of products "to meet the needs of the present without compromising the ability of future generations to meet their own needs" [6]. On the other hand, we also consider that the definition should incorporate the three dimensions of sustainability: environmental, economic and social, also called triple bottom line (3BL) [7,8]. Hence, the definition of sustainability that covers the purpose of this study can be referred to Ben-Eli [9] which states: "Sustainability is a dynamic equilibrium in the process of interaction between a population and the carrying capacity of its environment such that the

population develops to express its full potential without producing irreversible adverse effects on the carrying capacity of the environment upon which it depends".

Moreover, the textile sector is one of the most influential manufacturing industries in the global economy [10], but also, one of the most polluting. It is composed of a very complex supply chain [11] that comes with severe social problems [12,13]. The global fashion industry generates USD 1.3 trillion, employing 300 million people along the value chain [14]. However, many of the workers in producing countries such as Bangladesh, Cambodia, Sri Lanka, Vietnam, India and Pakistan receive the lowest minimum manufacturing wages [15].

This sector follows the traditional linear economic model, using virgin raw material, generating new textile products and discarding them—textile products are considered those categorised in section XI "Textiles and Textile Articles" of the International Harmonized Code System [16]—. Seventy-three per cent of the textiles are disposed in a landfill or incinerated, 12% are production losses, 14% are collected for recycling in lower-value applications such as mattress stuffing or insulation material and less than 1% is used to produce new textiles [14]. These figures demonstrate a lack of strategies in sorting fibres during the recollection process and recycling [17]. Most textiles and clothing are designed with a mixture of fibres whose composition is difficult to separate with the existing technology, resulting in non-recyclable fibres [18].

During the period between 2000 and 2015, the global trend shows an annual increase in clothing consumption and production of around 60% [14,19]. However, the use-time of clothes decreased 36% upon, on average, using each garment between seven or eight times [14,20]. The latter is observed mainly as a consequence of *Fast Fashion* (FF) business model. With origins in France, FF is a trend aiming at the female consumers who seek fashionable garments at an affordable price. FF's fundamental principle is to obtain quick knowledge about the needs of consumers [21]. There is no official definition for this trend. However, for this study, the authors use the definition generated by Caro and Martínez-de-Albéniz [19] who define *Fast Fashion* as "a business model that combines three elements: (a) quick response; (b) frequent assortment changes; and (c) fashionable designs at affordable prices". In fact, FF has given an economic boost to the textile industry. However, production and consumption practices are frequently related to adverse environmental and social effects. This business model consists of the production of small batches of garments with the latest fashion trends reaching the stores as soon as possible. This facilitates the continuous introduction of products to the market instead of only twice a year—Spring-Summer and Fall-Winter collection. Thus, it demands a quick response from suppliers, designers and producers in order to launch new garments in about six weeks [19].

Nevertheless, to put this business model into practice, it is necessary to decrease the quality of the clothes and, therefore, their lifespan. These garments are produced in low-income countries for wholesaling in Western markets. FF has triggered the consumer to purchase a large number of garments that will be used only a few times and then discarded. This consumption pattern increases the use of resources and material, as well as the generation of waste [22,23].

As opposition to *Fast Fashion*, the *Slow Fashion* (SF) concept emerged as a conscious movement against the current harmful consumption habits and the associated environmental and social impacts. This SF approach encourages the consumption of better quality garments that come from a sustainable supply chain. At the same time, SF represents a way to influence the consumer to invest in high-quality clothing that can be used for a more extended period and reduce the purchasing frequency [24,25].

In this context, this paper aims to analyse the current initiatives and innovations that seek for transitioning the textile sector to sustainable production and consumption patterns. These initiatives and innovations were classified concerning their origin at three levels: (a) stage of the textile life cycle, (b) initiator (government, private sector or civil society) and (c) technological advances. Additionally, this paper raises the focus of our shared responsibility since everyone is part of the textile industry value chain. The acquisition, use, and discard of textiles and clothing make us responsible for the impacts generated by this sector. For this reason, this paper claims the necessity to generate actions

to actively contribute to new textile production and consumption patterns through the creation and exchange of knowledge.

2. Methodology

A literature review was carried out to recount public and private initiatives, as well as technological innovations that have been developed in the last 11 years (2009–2020). An analysis was obtained of the successful practices, the failures, and omissions found in the system. A research question was established for this purpose: What are the initiatives that are being generated internationally towards a sustainable textile industry?

To answer this question, the initiatives and innovations founded are presented based on seven life cycle stages for textile products which were identified in the documents analysed: (1) fibre production; (2) textile production; (3) design; (4) clothing production; (5) commercialisation; (6) use and (7) end-of-life. An additional category was established for those initiatives covering more than one stage: (8) cross-cutting initiatives (Figure 1).
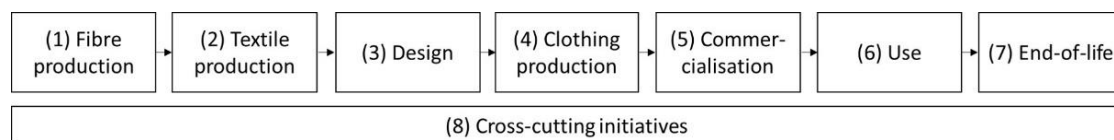

Figure 1. Life cycle stages for textile products.

The search criteria for this literature review were: (i) (textile OR apparel OR garment OR fashion) AND Sustainab*; (ii) "Smart textile" OR "e-textile" and (iii) textile AND social. The search engines used were: Scopus, ScienceDirect and Google Scholar, as well as Google to identify private or governmental initiatives. Using the keywords iteratively, 4245 documents published in peer review journals, government documents and sustainability reports were identified. This search was limited to open access documents written in English for the period 2009–2020. Subsequently, a first screening based on the title of the documents was carried out, removing duplicate items and selecting those that were related to initiatives aimed at improving the social and environmental performance of the textile sector. In this way, 597 documents were identified.

Additionally, the snowball technique was used to identify private initiatives, international standards and technological advances. Then, a second screening was carried out, reading the full abstract and checking the keywords that match the content of the document. Thus, 50 documents were analysed. Of which, 22% corresponded to documents published in peer review journals, 20% government documents, 16% sustainability reports and 42% private international standards initiatives and technological advances (Figure 2).
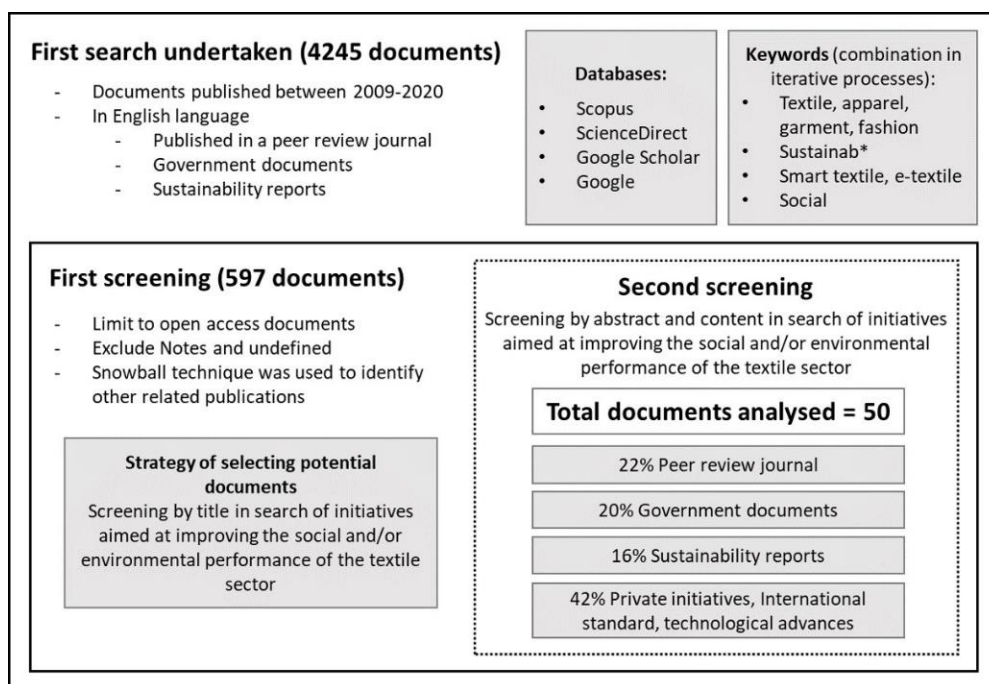
Figure 2. Literature review flow diagram. Adapted from [26].

3. Results

Due to the textile sector's importance, it is necessary to generate technological advances, private initiatives and government interventions to support the transition to new production and consumption practices. Under this scope, the innovations and initiatives are presented.

3.1. Fibre Production

The life cycle of any textile product begins by obtaining fibres, whether natural or synthetic [27]. Fibre consumption worldwide for 2018 was approximately 107 million metric tons, doubling the demand of the last 20 years [28]. Synthetic fibres such as polyester and nylon account for 60% of the market, dominating fibre production and consumption since the 1990s. Cotton represents 24% of global fibre production, and the rest corresponds to other fibres such as flax, wool, silk and cellulosic fibres [28,29].

Polyester and cotton are the most widely used fibres—synthetic and natural, respectively—nonetheless, the comparison between them is only conceptual, since each of them has particular characteristics, and one is not capable of replacing the other one [30]. However, it is important to know the environmental effects of both.

As polyester comes from fossil fuels, its production requires high energy consumption, which leads to the release of greenhouse gases (GHG) [31]. In this regard, the authors of [30]—through a Life Cycle Assessment (LCA)—found that the production of 1 kg of fibre into polyester consumes 60% more energy than cotton. However, obtaining polyester requires 0.1% of the necessary amount of water for growing cotton [30]. Likewise, Van Der Velden et al. [32] conclude that the production of polyester textiles, in general terms, has a lower environmental impact than the production of cotton textiles. Besides, polyester is extensively recycled, making it possible to reduce waste generation and environmental impacts of the products [33].

In the case of cotton, this comes from renewable and natural sources. However, its production involves the use of large areas of land, intensive use of water, pesticides and fertilisers [31,33]. For instance, its production represents approximately 25% of the global consumption of insecticides and 11% of the pesticides [34]. Likewise, to grow crops of cotton, between 7000–29,000 litres of water are

consumed per kilogram of fibre—the variation depends on the type of the cultivation system—[34,35]. Furthermore, during the spinning process, cotton presents a material loss of 20%, while in the case of polyester, the loss is about 2–3%, mainly due to the uniformity in the length of the polyester fibres [30]. On the other hand—regarding the social aspect—the cultivation of cotton is positioned in second place with more child labour and forced labour. These working conditions are present in 17 countries [36].

For this reason, the adoption of new materials and recycling of products to decrease the virgin material use can significantly reduce the environmental impact [37,38]. Nevertheless, it is necessary to highlight the importance of the environmental assessment of current and new materials, to be informed about their environmental performance and acquire the appropriate information to improve the decision-making process on cleaner production.

In this context, the company Tencel has developed fibres derived from cellulose [39], and Bemberg is investigating new fibre sources [40]. There is also ITMA, a textile technology platform, which, in 2019, was focused on the production of recycled fibres [41]. For its part, Beaulieu International Group launched UltraBond: a latex- and binder-free fibre that reduces energy and water consumption and the generation of emissions [42]. These and other initiatives [43,44] (Table 1) are being used to search for innovative materials representing a more sustainable option for the textile sector [17].

3.2. Textile Production

After the fibres are obtained, the following process is the yarn-spinning. This process encompasses opening, carding, combing, drawing, roving, spinning and winding [45]. Then, the next step is the manufacture of fabric, which is carried out by weaving, knitting, dyeing, finishing, washing and drying, all of them highly dependent on the final product type [27]. These two processes have a considerable environmental impact due to the intensive consumption of electricity. For this reason, the use of technology that allows efficient use of electricity is crucial [32,46,47].

Once the fabric is manufactured, a pretreatment process is applied in which pretreatment consists of physical and chemical processes that are applied to fibres and textile products before beginning another process. Those processes can be applied to fibres, yarns and fabrics, depending on the type of product and the features sought [48]. The physical processes are intended to provide textures and finishes to fabrics using mechanical means. Chemical pretreatment consists of applying different chemical substances to textile materials, to improve their hydrophilic properties and their affinity for colourants [48]. There is a wide variety of pretreatment processes, depending on the desired result [49], e.g., bleaching, pH modification and water repellence, among others [46]. This stage involves significant use of chemical substances. Generally, the textile industry uses around 15,000 chemicals throughout different processes [50]. Some of these chemicals can be harmful to the environment, workers and even the consumers [51,52]. Such is the case of formaldehyde, which increases the risk of leukaemia and brain cancer in workers who are exposed to high concentrations [53]. In this regard, due to the risk to human health and the environment, some statutes regulate the use of the chemicals [54–56]. This regulation applies to the manufacturing process [57] and the finished product [58].

Finally, the dyeing and finishing processes are carried out to give the fabric the desired appearance and remove chemical substances, e.g., washing, coating and printing. Dyeing and finishing processes involve multiple uses of chemicals, water and electricity [31]. For this reason, these processes represent a significant environmental impact since they generate a high amount of hazardous waste and water discharges [51]. The dyeing process consumes between 15 and 20% of the total water used in the textile industry. Average water consumption is 30–50 litres per kg of material; this directly depends on the type of dye used [59].

For this reason, proper chemical selection and use of non-water technologies are crucial. In this sense, biodegradable, reusable and water-free chemicals have been developed to replace dangerous substances [51]. Besides, technological advances are reducing the use of water and energy [38]. Easton [60] and Khatri [35] reported advances in textile dyeing, which have been shown to have better environmental performance. These advances are based on ultrasonic energy, electrochemical and

microwave methods that present reduced energy, water and chemical consumption. Even further, those advances result in improving the colour yield quality and the reduction of effluent concentration.

Additionally, the Dutch company, DyeCoo [61], has developed a textile dyeing system which is free of chemicals and water. It uses only CO_2, dyes, electricity and steam. It is currently in operation in six different companies located in Vietnam, Thailand and Taiwan. It is planning to expand to India and Europe in 2020. This process obtains results of the same quality and characteristics as the conventional dyeing process, but without residual water. This new technology reduces energy consumption by approximately 60%, which allows companies to reduce their carbon footprint and dyeing time [62,63].

On the other hand, even when there is no global regulation for the textile industry, which generates a lack of coordination and common standards [64], several international certifications have emerged to guarantee the production of cotton free of toxic substances. It is also possible to find several eco-labels on environmental and social aspects developed for the textile industry. Among the most common certifications are (i) Global Organic Textile Standard (GOTS) [65] which forbids the use of chemicals which are dangerous to health and also regulates the water and energy consumption and; (ii) Organic Content Standard (OCS) [66] which guarantees the traceability of organically grown materials. Similarly, there are initiatives to promote sustainable cotton production in different countries, e.g., (i) Cotton made in Africa [67], Cotton Australia [68] and Better Cotton Initiative [69]; while referring to the conditions of textile manufacturing arises OEKO-Tex® [70], which analyses the sustainability of production plants, seeking to optimise production conditions. Likewise, Bluesign Technologies AG [71] regulates the hazardous chemicals management, materials and substances, avoiding toxicity risks. Additionally, it evaluates the use of resources, occupational health conditions and customer satisfaction, seeking to generate sustainable products. Some of these certifications also offer an eco-label.

Eco-labels promote proper manufacturing practices, minimise the presence of hazardous substances in products [72] and are used to communicate this information to customers [73]. They are based on evaluation criteria developed by independent organisations, which is more reliable and objective than the producer's information [74]. The authors of [73,75,76] describe and analyse various eco-labels. Some have been generated depending on the country or region such as The EU Ecolabel [77], Blue Angel [78] from Germany and Eco-Mark [79] by Japan, which, in addition to textile products, cover a wide variety of products. Additionally, eco-labels depend on the stage of production, e.g., Fairtrade Standard for Cotton [80] and Cradle to Cradle [81,82].

3.3. Design

At this stage, the designer decides what textiles and garments will look like. The process ranges from the choice of texture that will be used to generate the patterns that will feature the new products. In this respect, designers play an essential role in the transition to the sustainable textile industry, since they are the ones who generate new trends and thereby, the range of future products.

For this reason, it is fundamental that designers and large producing brands have a sustainable approach. It is necessary for taking care of the use and origin of resources, the duration of products, the working conditions, consumer satisfaction and the final disposable strategies or the recycling of the consumed products.

Currently, many designers integrate a sustainability approach to their products, whereby it is crucial to be informed about sustainability aspects, such as knowing the origin of textile products and clothing at the time they are being purchased. For this reason, diverse research and tools have been carried out supporting the designers throughout this process. Such is the case in the study conducted by Sherburne [83], where design strategies are identified seeking to reduce the environmental impact of garments through questions and exercises that facilitate the development of models with a life cycle approach. Likewise, Niinimäki and Hassi [84] presented the consumer needs and priorities on textile sustainability issues, based on online questionnaires conducted in Finland to a random sample of 500 respondents. The questionnaire included topics related to clothing purchasing, interest in design strategies and product lifespan. Besides, Kozlowski et al. [85] developed a tool to support designers

to create sustainable fashion brands, especially in small- and medium-sized enterprises, looking to reduce negative impacts through the design generation by creating positive economic, social and environmental impacts.

3.4. Clothing Production

Once the fabric is ready, cutting and sewing are continued [86]. In this regard, 99% of the global textile sector is made up of SMEs. Of which, 69% of such producers and suppliers are located in Asia, followed by 29% in Europe and 2% in Africa [87,88]. It should be noted that one of the most alarming aspects of the production phase are the working conditions of the thousands of workers in developing countries. Those unsafe working conditions were the cause of the tragedy in Plaza Rana, Bangladesh (April 2013), where 1130 workers lost their lives [12].

In response to this latter event, the Alliance for Bangladesh Worker Safety [89] was created, with the participation of various textile manufacturing and retailer brands, the Bangladesh government, non-governmental organisation (NGO) and worker protection organisations. In this alliance, each member must ensure the right conditions of the facilities and safe workspaces, especially the building's infrastructure, electrical installations and fire prevention. Its operation is based on training and empowering employees to achieve safe working conditions [89].

From the beginning of the alliance (2013), 93% of the remediation works on affiliated factories have been completed, involving 1,305,310 workers. Out of a total of 714 factories signed, 654 are active, and 178 are suspended. Some of the benefits offered to the workers are training on awareness about health and safety, problem solving, development of relationships with partners and superiors, reduction of diseases and work accidents. Other beneficial effects are related to the improvement of a tension-free environment, and work skills with wage increase [89].

Likewise, the Fire and Building Safety in Bangladesh Accord was signed in 2013 between brands and trade unions. This accord has the objective of improving the work conditions of the textile industry in Bangladesh. It is a commitment made by the signatory brands to ensure enough funds to repair and maintain the facilities conformed with by 190 brands, more than 1600 factories and around 2 million workers [90]. All factories producing for signatory brands are subject to fire safety, electrical and structural inspections, as well as continuous remediation monitoring. In case the inspection identifies an immediate danger caused by the poor conditions of the building, the factory and owner are requested to evaluate the facilities and stop production until the safety of the building is determined and until corrective measures are taken [90].

In a global context, particularly the developing world, many factories in the sector do not comply with the minimum wage laws, and the wages paid do not meet the basic needs of the workers. Situations like this often result from weak or non-existent governance interventions to generate collaborations between public and private actors to promote better working conditions. Therefore, it is essential to generate regulatory frameworks and legal systems in which there is a participation of big producers and government to make appropriate labour adjustments [18].

In this particular regard, one of the good governance initiatives comes from the Netherlands. In July 2016, the Dutch government signed the Dutch Agreement on Sustainable Garment and Textile (AGT), urging Dutch companies with productive activities inside or outside the country to reduce risks and take responsibility [88]. The main objective is to improve working conditions, reduce environmental impact and resources' use, as well as to promote animal welfare and increase the transparency of the productive chain contributing to Sustainable Development Goals [1]. The AGT establishes the annual requirements that companies must meet, including the activities of their suppliers [88]. It is in this way that the Netherlands became the first country to generate an initiative of this kind, which was later followed by Germany [91].

The technological perspective has brought great benefits to the textile industry. It has simplified production, facilitated the just-in-time approach, reduced inventories and storage, as well as reducing the waste from the production process. Automation can avoid repetitive and dangerous tasks for

workers, which will allow them to concentrate on more creative and rewarding activities, bringing social, environmental and economic benefits. However, automation has also replaced the human workforce, which results in a decrease in jobs [92]. Such is the case of automation in the process of cutting garments by laser, which has evolved rapidly, performing the cutting task in less time, reducing accidents and occupational diseases [92].

3.5. Commercialisation

This stage consists of transporting, exporting and distributing the product to reach the customer. In this regard, China is the largest exporter, with 37% of international textile exports, followed by the European Union with 23% [10,93]. Textile producers and marketers play a critical role in the commercialisation stage because they have the necessary influence to mark the movement and fluency of the commercialisation of textile products and clothing.

For this reason, managers of international fashion production and distribution companies such as H&M, Bestseller and Target have formed a collaboration forum of the textile industry in sustainability issues, the Global Fashion Agenda (GFA) [18]. The GFA aims to bring together the industry leaders and establish actions to improve the sustainability performance of the textile sector in its production, marketing and consumption schemes. The GFA also organised the Copenhagen Fashion Summit, a leading business event in the fashion sustainability world [94], where the leaders and decision-makers of the fashion industry attend. Likewise, an annual report called Pulse of the Fashion Industry is published [20].

Additionally, the Sustainable Apparel Coalition (SAC) was established [95], which brings together the leading international brands, distributors, producers and government institutions to generate sustainability initiatives in the fashion industry. In this way, the report published by GFA provides an evaluation of the environmental and social performance of the fashion industry, as well as a guide to sustainable improvement based on data obtained from the Higg Index [95]. This index has been generated by SAC and consists of a tool to measure sustainability in the textile industry, available online for SAC members, which evaluates the environmental and social impacts of a particular company concerning the installation, brand and products.

Even further, how the products are sent to consumers has broadly changed along the time, and even though it has always been possible to rent a dress, tuxedo or costume, the trend of the textile industry is to carry these rental schemes to everyday wardrobes. There are currently companies that offer clothing subscription services, in which customers pay a weekly, monthly or annual fee to rent a specific number of garments. This allows consumers to change their wardrobe frequently without acquiring new clothes, reducing the use of new materials and the generation of waste. Such is the case of companies like Rent the Runway [96], Armoire Style [97], Gwynnie Bee [98] in the USA; Glam Corner [99] and Ekoluv [100] in Australia; Mud Jeans [101] in the Netherlands and YCloset [102] in China.

3.6. Use

Currently, the main markets for textiles and clothing are the European Union with 36% and the United States, with 14% [103]. It is estimated that the clothing consumption around the world is equivalent to 62 million tons, being responsible for the annual consumption of 79 billion cubic metres of water and the emission of 1715 million of CO_2 tons emitted [20].

The global trend shows the consumer acquires twice the amount of clothing than 15 years ago, but, keeps them half the time. On the one hand, it is estimated that if the wearing time of a garment were twice the current use-time, the emission of GHG would be reduced by 44% [14]. On the other hand, it is expected that by 2030, the consumption of clothing will increase by 63%, which is equivalent to 102 million tons [20].

As it was mentioned previously, a large part of the environmental impact generated by the textile products' use is derived from the water consumption and electricity during the washing, drying and

ironing cycles [104]. For this reason, lowering the washing frequency, temperature and quantity of detergents used is a direct way to reduce the impact generated by the use of clothing [32,105].

Likewise, new technologies have given way to a new generation of textiles, seeking to satisfy new customer needs. Some of these innovations are aimed at improving environmental performance [106]. This is the case of nanotechnology applications that provide high durability to the products and different properties, e.g., self-cleaning textiles. These new products have dust and dirt repellence, reducing significantly the washing cycles necessary to keep the garment in good condition, and hence reducing the use of resources. This feature is attributed to two different procedures: (i) the use of microscopic particles that avoid dirt from lodging in the textile and making dirt easy to remove and (ii) an application of a photo-catalytic layer that destroys dirt with exposure to sunlight [104].

On the other hand, to reduce the consumption of clothing, a new business model has emerged. This new initiative proposes that people share their wardrobe of branded clothing with other people in their local area, renting them for a specific time. This business model of Tumnus [107], The Volte [108] and Style Lend [109] avoid having garments that are not frequently used, taking up space in a closet, and turn to earn some extra money.

Likewise, in response to the needs of the market, technological advances have developed the so-called electronic textiles—also called smart textiles or e-textiles—which seek to meet new customer needs, increasing their demand rapidly. These textiles include electronic devices that provide added value to garments, especially in sporting goods, outerwear, health care and institutional uniforms [110]. For instance, this is the case of e-textiles which have been developed in the medical area to support the treatment of various diseases and conditions. Garments can use vibration therapy to contribute to the healing process when there is discomfort in the skeletal muscle system [111]. They can also be used as bioactive bandages containing drugs which are released in a medically prescribed dosage to treat wounds and different ailments [112,113]. Further, it can provide more comfort and functionality to hospital attire [114].

However, both e-textiles and self-cleaning textiles still require a detailed sustainability analysis, since even though they are capable of providing significant benefits, their mass production can accelerate the rate of consumption of natural resources as metals [115]. In this regard, a lack of training and information has been detected in the developers of textile technologies in sustainable design issues. This could represent a potential risk of these products since their intensive use can generate a new type of waste [116].

Due to the high degree of integration of different materials, the re-use becomes particularly complex. Hence the need to separate the textile material from the electronics, not to mention that many of them can contain both precious metals and a wide variety of harmful substances to health and the environment in their post-consumption phase. In this regard, recycling companies seem to pay little attention to textile recycling issues [111,116].

3.7. End-of-Life

In 2015, 92 million tons of textile waste was generated around the world, and by 2030, an increase of 62% is estimated [20]. Thus, to face this global problem, in 2017, the Ellen MacArthur Foundation launched an initiative integrating several brands and different actors in the textile production chain. This initiative aims to adopt a Circular Economy (CE) approach, with durable designs that allow re-use and recycling [14].

Likewise, in 2015, the European Union launched a strategy based on Circular Economy for different products including textiles [117]. Later, in 2017, this proposal was adopted so that for the first time, textiles will be collected separately by the Member States, a goal that must be achieved by 2025 [17]. In response to this plan, the Netherlands has generated a strategy to achieve 100% circularity in the textile industry by 2050 [63], to which Sweden [118] and France [119] have joined with their strategies. Besides, other projects have been developed under CE approach, such as: (i) RESYNTEX [120], a large-scale project to develop new biochemical recycling technologies for

post-consumer textile products and the establishment of symbiotic productive parks; (ii) ECWRTI [121], wastewater treatment project of the textile industry and; (iii) e-Biz 4.0 [122], which seeks to connect companies to generate a more efficient and traceable supply chain [93].

Additionally, there are several private initiatives like ReBlend [123], a company dedicated to converting discarded textiles into new threads and products. This company seeks to reduce the use of virgin material resources by recovering seven tons of post-consumer garments and generating six tons of 100% recycled yarn, which reduces energy use by 33%, water use by 62% and GHG generation by 18% [124]. Besides, Texperium is also a Dutch innovation centre dedicated to the generation of new materials in order to provide solutions to the problem of industrial textile waste [125].

However, although the number of companies that have integrated a circular model is continuously increasing, the transition seems to be slowly implemented. The reasons for this may be associated with regulatory frameworks, logistics, technology and cost frameworks, as well as to the lack of adequate infrastructure [18]. Therefore, it is essential to keep generating efforts and strategies that contribute to post-consumer use and waste recycling.

3.8. Cross-Cutting Initiatives

More and more companies and public and private organisations are adopting strategies that help the textile sector to move towards sustainability [126]. There are initiatives focused on several life cycle stages simultaneously; for example, the project called European Clothing Action Plan—ECAP [127]. This project aims to generate design, production, consumption, collection, recycling and processing strategies to improve the performance of the textile industry in Europe. It focuses on the supply chain and on reducing textile waste through effective garments' recovery. Retailers, brands, suppliers, public sector and recycling organisations are involved. Throughout the project, participants will develop circularity strategies to reduce waste, offering business benefits by reducing the environmental footprint of textile products.

As an example, the United Kingdom, through the reinvention of design, has generated an initiative that brings together governments, businesses and communities, giving rise to the Sustainable Clothing Action Plan (SCAP) and the campaign called "Love your clothes" that aims to accelerate the transition to efficient use of resources and a sustainable economy [128]. SCAP acts as a framework of collaboration as a voluntary commitment based on generating a more efficient garment life cycle. It is based on efficient business models in the resources' useful life prolongation, consumer behaviour study, fibre selection, re-use and recycling [129].

Similarly, the Clean Clothes Campaign [130] is a global alliance dedicated to improving the working conditions of the textile industry, involving the following countries: Germany, the Netherlands, Austria, Belgium, Czech Republic, Finland, France, Ireland, Italy, Norway, Poland, Spain, Switzerland, Turkey and the United Kingdom.

In the standardisation and certification initiatives for this sector, standards such as Fairtrade Textile Standard [131] and CSC 9000T [132] have been developed. The first one regulates fair trade in textile supply chains, and the second is a Chinese Standard based on international regulations and conventions to regulate the textile products' traceability. All in all, it is possible to appreciate the different initiatives that face the problem of the textile sector, through the awareness and concrete actions of the stakeholders involved. However, it is not an easy task because efforts to improve the performance of the textile industry in terms of sustainability can increase product prices. Thus, consumer acceptance will be addressed simultaneously, and one way of doing so is by increasing awareness among consumers about current consumption patterns. In this respect, the acquisition of fewer garments would result in a decrease in profits for the sector, which would jeopardise the economic survival of some brands. Whereby it is necessary to generate strategies that prevent damage to the sector unless consumers are willing to pay higher prices [17,24,25]. Table 1 is presented as an overview of the main initiatives found in this research.

Table 1. Overview of main initiatives found in this research.

LCA Stage	Initiative	Initiative Type	Initiator				Geographic Scope	
			Government	Private	Academy	NGO	International	Regional
1. Fibre production	Tencel [39]	Development of new materials		X			X	
	Bemberg [40]			X			X	
	ITMA [41]			X			X	
	UltraBond [42]			X			X	
	Lenzing [43]			X			X	
	S. Vilarrasa [44]			X			X	
2. Textile production	KEMI [55]	Regulation	X					X
	REACH [56]		X					X
	Restricted Substances List MRSL [57] and RSL [58]			X			X	
	Khatri [35]	Technology development			X		X	
	Easton [60]; DyeCoo [61]			X			X	
	GOTS [65]; OCS [66]	Certifications and eco-labels		X			X	
	Cotton made in Africa [67]; Cotton Australia [68]					X		X
	Better Cotton Initiative [69]					X	X	
	OEKO-Tex [70]; Bluesign [71]; Cradle to Cradle [81]			X			X	
	Fairtrade Standard for Cotton [80]			X		X	X	
	Eco-Mark [79]			X				X
	The EU Ecolabel [77]	Eco-label	X					X
	Blue Angel [78]		X	X				X
3. Design	Sherburne [83]	Strategies and tools			X		X	
	Niinimäki and Hassi [84]			X	X			X
	Kozlowski et al. [85]				X		X	
4. Clothing production	Alliance for Bangladesh Worker Safety [89]	Multi-stakeholder alliances	X	X		X		X
	Fire and Building Safety in Bangladesh Accord [90]		X	X		X		X
	AGT [88]		X	X		X		X
	Partnership for Sustainable Textiles [91]		X	X		X		X
5. Commercialisation	Global Fashion Agenda [18]	Collaboration forum		X			X	
	Sustainable Apparel Coalition [95]	Multi-stakeholder alliance	X	X	X	X	X	
	Rent the Runway [96]; Armoire Style [97]; Gwynnie Bee [98]; Glam Corner [99]; Ekoluv [100]; Mud Jeans [101]; YCloset [102]	New business model		X				X
6. Use	Tumnus [107]; The Volte [108]; Style Lend [109]	New business model		X				X
	Busi et al. [104]	Technological development			X			X
	N. M. van der Velden et al. [111]				X			X
	U. S. Toti et al. [112]				X			X
	L. F. Zemljič et al. [113]				X			X
	G. Song et al. [114]				X			X
7. End-of-life	Ellen MacArthur Foundation [14]	Circular Economy		X		X	X	
	EU Circular Economy [117]		X					X
	Circular Economy in the Netherlands [63]		X					X
	Circular Textile Initiative [118]					X		X
	RESYNTEX [120]	Recycling technologies		X				X
	ReBlend [123]			X				X
	Texperium [125]			X				X
	ECWRTI [121]	Waste treatment		X				X
	eBiz 4.0 [122]	Traceability platform		X				X
8. Cross-cutting initiatives	ECAP [127]	Plans and programs	X	X		X		X
	SCAP [129]			X		X		X
	Clean Clothes Campaign [130]					X	X	
	Fairtrade Textile Standard [131]	Regulation of Fair-Trade Textile Supply Chains		X		X	X	
	CSC 9000T [132]		X	X		X	X	

Source: Own elaboration.

4. Discussion

All stages of the life cycle of textile products are intimately connected, so it is crucial to generate actions systematically. It is necessary to continue promoting agreements involving all stakeholders to solve the problems of each stage. These agreements will foster collective effort and commitment to achieve the same goal, preventing actions taken by a few from losing strength and effectiveness.

In this sense, regarding the intensive consumption of natural resources, the development of new alternative sources of both natural and synthetic fibres is indispensable. It is elementary to promote the investigation of new materials that contribute to reducing the consumption of resources, as well as the integration of recycled materials into the production chain. At this stage, the private initiative that has developed research in different areas stands out internationally (Table 1). However, it is required to generate monetary funds that encourage academic and business research; as well as disseminate and apply the findings. Although, avoiding that significant initiative remains only at the experimental level. Similarly, it is essential to promote the production of fibres free of toxic substances and regulate this process through existing certifications.

Besides, it is indispensable to include sustainability issues in the training of new designers and train those already established. The purpose is to raise awareness about the vital role they play in the production and consumption patterns of the sector. In this sense, it was identified that designers, companies and a large part of consumers frequently have a misconception of what sustainability implies in the textile industry. This reflects a deep lack of information in the entire society. Therefore, an effort is required from designers, universities and companies to train professionals to meet the needs of the sector.

Concerning the stage of clothing production, it was possible to identify it as one of the stages with the most significant impact, both social and environmental, due to precarious working conditions and lax environmental regulations in producing countries. In this regard, industrial development in low-income countries needs to be disengaged from exploitation due to lax legislation and economic necessity. Working conditions, the health and safety of the workers and the community must be improved.

As shown in Table 1, it is possible to identify important movements that were generated in the Asia region following the accident that occurred in Bangladesh. Multi-stakeholder agreements have achieved significant improvements in working conditions of the thousands of workers that make up the sector, as well as environmental regulations that truly safeguard the well-being of ecosystems.

Likewise, the active participation of workers' unions and dialogue with their employers plays a crucial role in the adoption of new technologies and process automation. In this regard, the creation of multi-objective agreements in Europe and the development of technology and automation intentionally stand out. Besides, it is essential to generate training schemes that allow workers to adapt to the introduction of new equipment to avoid dangerous tasks. This will allow them to keep their jobs while taking advantage of their skills in activities that involve greater creativity and dexterity. In this regard, it is imperative to increase the participation of the government and educational institutions that support the adoption of new technologies by providing adequate training to their communities.

The abovementioned is a sign that, in order to improve the sector substantially, it is needed to know it thoroughly. For this reason, the evaluation and generation of sustainability data is an important piece for the development of strategies that can positively influence the sector. Moreover, to achieve this task, it is required to promote the transparency and traceability of the production chain, to generate an integral connection between the different production stages. This is possible through the adoption of international standards that regulate the use of resources, working conditions and traceability, which in turn are aligned with regional norms and laws.

In the commercialisation stage, new business models have emerged internationally, which are based on changing customer behaviour and contribute to reducing the environmental footprint generated. Besides, several multi-stakeholder groups made up of large brands and transnational companies were identified, as well as information and tools on the subject of sustainability for affiliated companies. However, there is very little information aimed at SMEs, which leaves an important segment unprotected, as this portion of the productive sector rarely has the economic and human resources to generate projects or strategies in environmental and social matters, leaving them vulnerable to market changes.

Regarding the use of textile products and clothing, environmental impact studies and awareness campaigns on the acquisition and use of textiles and clothing at international level were found. However, it is necessary to continue generating strategies involving government, private sector and consumers, since even though there is a great interest in certain consumer groups, it is a difficult task that requires the active participation of all. It is needed to produce garments of higher quality that may be useful for longer, as well as the generation of rental strategies and loan of wardrobes. To this aim, the participation of NGOs for consumer awareness is fundamental in changing the current *Fast Fashion* scheme. Likewise, it is required to generate campaigns for the use and washing of clothing, which better inform the consumer of the requirements presented by the products regarding the use of electricity, water and detergents. In this regard, the development of new washing, drying and detergent technology equipment is crucial to reduce the environmental burden of using textiles.

In the end-of-life stage, the efforts generated in Europe and the United Kingdom to integrate Circular Economy models in production processes, as well as in the generation of new recycling methods, stand out. This stage is a strategic point to generate a change in the environmental performance of the textile sector since through the differentiated collection and re-use, a significant reduction in the virgin material use can be generated, for which the involvement of government, producers and consumers is a central piece. It is indispensable to generate products that are easy to use post-consumer and recycle, allowing the integration of discarded textiles into a new production chain. For this reason, it is recommendable to generate collection strategies of textiles post-consumer, as well as fibre separation and recovery processes that promote Circular Economy schemes.

In this sense, the extended producer and consumer responsibility are indispensable since it cannot be only government responsibility to deal with large amounts of waste generated annually, as producers and users also have a part in this problem.

On the other hand, the generation of new products without a prior feasibility study on sustainability issues identifies a potential risk. Such is the case of the development of new technologies such as nanotechnology and e-textiles, which can become a waste problem if mass marketing is done.

In general, the actions identified through this research are aligned in the same direction; however, it is essential to link these efforts and the stages, to ensure their success and effectiveness. The task is complex, and without integral work between government, producers, workers and consumers, it will not be possible to generate substantial benefits in the sector. The active participation of all stakeholders is indispensable, as well as the generation of strategies, certifications, standards and laws that regulate the performance of the sector.

5. Conclusions

Through this literature review, some of the initiatives aimed at increasing the sustainability of the textile sector were identified. It was found that a large part of the government initiatives are designed to improve the working conditions of workers in the sector, especially in Asia. These initiatives are mainly influenced by NGOs and workers' unions, who, in turn, have achieved the participation of employers and private initiatives. Likewise, the private initiative formed by big brands and producers have been given the task of generating partnerships to set actions and goals in sustainability issues. The generation of stricter laws and regulations is crucial, as well as the promotion of certifications to regulate the sector and increase transparency and traceability. It was identified that most of the innovations and actions towards sustainability are focused on the clothing industry under the economic, environmental and social importance that it entails.

Besides, given the lack of information, it is required to generate actions focused on sustainability training of SMEs that make up the supply chain of large companies. In this way, it will be integrated into a fundamental part of the textile sector supply chain, avoiding displacement risks due to the lack of compliance with the standards established by large companies, in the absence of support and training.

The textile sector is exposed to constant changes that demand great flexibility and adaptability. For this reason, it is elementary to have enough information to give a prompt and accurate response,

taking into account the economic, social and environmental aspects. Thus, it is necessary to monitor in depth the sustainable performance of the sector and generate tools that contribute to the industry transition. In this way, companies can carry out actions and improvement plans autonomously, improving their performance gradually towards a sustainable textile sector.

For this reason, as future work, the generation of a methodological tool that guides the company in measuring its sustainability performance is presented, as well as in the generation of continuous improvement strategies that facilitate the transition of small- and medium-sized enterprises.

Through this research, it was possible to identify the technological advances developed, the agendas and initiatives carried out by governments and private companies, as well as the progress achieved in sustainability issues in recent years. However, it is very important to emphasise that the number and type of initiatives require frequent revision due to the relevance of the topic and the ongoing efforts being made.

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