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Framework Of A Circular Model For Textiles: A Review

[1]Sulagna Saha, [2]Nand Kishore Baraik

[1]Assistant Professor, [2]Assistant Professor

[1]Department of Fashion Technology,

[1]National Institute of Fashion Technology, Bhubaneswar, India

Abstract: This paper aims to identify the challenges faced by the linear textile model and provide a framework for its transition to a circular model. An extensive literature review was done to study the research undertaken in the last ten years. The review was conducted specifically for study papers related to the topic. Studies that extensively discuss sustainability, environmental impacts, alternative solutions, economic implications and the way forward have been reviewed and analysed. The literature review analyses numerous working papers, institutional reports and journal articles published by individual authors. Textile and apparel manufacturing is significant in any economy, employing about 2 million people. Yet, the supply chain of the existing apparel business model is very polluting, uses a vast amount of non-renewable resources and generates a high volume of waste. The increase in apparel production and consumption habits results in almost 87% of textile waste incinerated or discarded in landfills. These environmental concerns can be addressed if the textile sector shifts to the circular model. The paper provides a new interpretation of existing sources on circular economy and offers new insights into the topic area by emphasizing its relationship with collaborative working.

Index Terms **-** Circular Economy, Linear, Recycling, Waste

I. INTRODUCTION

The traditional linear model of the economy is increasingly becoming obsolete as it does not fit with the sustainable development goals. The circular economy, on the other hand is becoming more and more popular across all sectors. The "Circular Economy" (CE) is often defined as an organized system to restore and regenerate through technology and design. It uses the natural resources in an optimum way [1]. The concept of CE includes various principles like designs that are sustainable and results to zero waste, increasing the life span of the product, recovery of natural resources and services towards repairing and remanufacturing [2]. The circular model is based on the 3Rs, i.e. "reduce", "reuse" and "recycle". These 3Rs has to be applied across the complete production, consumption and disposal stages. The model thus needs engagement of all stakeholders [3]. Where the linear model talks about "take, make use and dispose", the circular model aims at replacing the concept of end-of-life for any product. It concentrates on restoration of natural resources, usage of renewable energies, removal of the use of the toxic chemicals and eliminating waste from any product life cycle through better design and usage of better quality of materials [1]. However, the processes involved in any circular model are not standardized. The limitation of the linear model is very prominent in the textile and apparel sector. The need of this circular model is also emphasized by experts and practitioners from the industry [4].

II. LITERATURE REVIEW

2.1 Traditional linear model and its limitations

Textile and apparel manufacturing hold a major share in any economy. According to the annual report of Euratex [5], 177,700 companies from apparel and textile sector provided employment to over 1.7 million people in 2016. The sector had an yearly turnover of €171 billion. It is also one of the biggest in terms of sales with $450 billion global sales [6]. However, it is also the most environmentally hazardous industry [6]. The environmental concerns include the energy usage, use of water and toxic chemicals, CO2 emissions and solid wastes [6].

In recent years, a number of factors have contributed to the increase of the environmental issues in the textile and fashion sector. The most important factors that results to environmental problems caused by the textile industry is dependent of the increase in consumption patterns due to fast fashion [7]. The "fast-fashion" business model started in the 1980s. Within next 5 to 10 years it became more competitively priced with discounts and thus gradually changed the expectations of the consumers and their consumption habits [8]. The competition urged companies to reduce costs and streamlining their supply chains. This reduced the prices even more and made fashion affordable [9]. The lead times were also reduced so that more collections and lines can be launched frequently. Almost all brands has on an average doubled or more their number of collections annually [9]. The reduced prices and more variety have influenced the consumer to buy more. From 2000 to 2014, there has been an increase of 60% of purchase of garments by an average consumer [1]. According to a McKinsey report, if 80% of the population from the emerging economies reaches the apparel consumption level of the western world by 2025, and no measure is taken to make the textile sector environmentally efficient, then the ecological footprint of the industry with grow more stronger [9].

The consumption patterns of any average person have significantly increased. From 1996 to 2012, the volume of clothing purchased by an average European has increased by 40% [10]. The expenditure on apparels accounts for 4.2% of total household expenses. In addition to this, the lifespan of the clothes has decreased and thus it is used for a shorter time period and then disposed [11]. According to a report by McKinsey, consumers retain clothes about half the time that they did 15 years back [1]. The economic growth is dependent on launching and promoting new product and disposing old ones. This is even easier in fashion as the obsolescence factor is very high as style norms dictate that [12]. Consumers buy more than required and treat the cheaper ones as disposable. Studies indicates that lower priced garments are often discarded after only seven to eight wears [1]. The lower value apparels are also difficult to reuse as these goes out of fashion very quickly and is made with lower quality standards like colour fastness, dimensional stability and durability [11]. The clothing manufacturing has doubled from the year 2000 to 2014 [1] due to the reduced prices, increased demand and the ability of the consumer to spend. This trend may continue due to the fact that the population is growing with more and more share to the middle class and rise of standards of living [13].

As result of the increase in apparel production and consumption habits, the demand for fibres is also rising which in turn is resulting in huge volume of textile waste [14]. In 2016, the consumption of fibres globally was 99 million tons. More than half of this volume (62.7%) was synthetic oil-based fibres. 24.3% was cellulosic and protein based, 6.6% was wood-based, 5.3% of other natural fibres and 1.1% of wool. To meet the rising demand in fashion, the fibre production is also increasing. It has grown at a rate of 3.7% per annum. In 2013, it was 85.5 million tons and by 2025 it is estimated to reach 130 million tons [10,15]. In 2018, the volume of annual production of fibres was 107 million tons [16](16). The two most important fibres for the textile sector is cotton and polyester. In 2018, 56 and 26 million tons respectively were produced for cotton and polyester fibre [16](16). These are estimated to increase by 40% in 5 years [17]. Both cotton fibres and polyester fibres affects the environment [18]. Synthetic fibres produced using non renewable energy sources result in major greenhouse gas emission. The by-products of this production are often disposed of with waste water. The fibres are also not biodegradable [13,14]. Cotton, on the other hand, though biodegradable, also takes a toll on the environment with an 25 million tons of production per annum [13,14]. Cotton production requires huge volume of water, pesticides, fertilizers and land [14]. It is also one of the biggest contributor to pesticide related illness and the toxic chemical used in finishing and dyeing damage the soil fertility when discarded [13].

These environmental concerns can be dealt with if the textile sector shifts to the circular model. Reduced consumption patterns, retaining clothes longer, recycling and reusing apparels can reduce the demand. More and more fashion brands are recognizing the fact that the linear model is dysfunctional.

The limitations of the linear model have encouraged researchers to look for newer methods to recycle textiles. 60% of textile consumption across the world consists only of apparels [19]. 53 million tons of fiber is produced to cater to clothing needs. Only 12% of these fibres are recycled and 73% of these end in

landfills or are burned [19]. 97% of raw materials required for apparel manufacturing are from original feed. 63% of this volume is synthetic and 26% is cotton [19]. Cotton as a pure fibre is biodegradable as well as can be recycled using chemicals or mechanical methods to be spun again into new yarns. However, cotton and polyester blends are difficult to handle and yet is the most popular in current market. A number of processes and methods involving different solvents can be used to separate fibres in blended form.

2.2 Circular Economy

For the reasons stated above, the circular model of economy has become more and more popular over the last decade as a mean to reduce the impact of production and resources used on the environment. The concept of CE aims at circulating the resources over and again and thus reducing the pressure on the non-renewable resources of the world [20]. It deals with the extraction of resources and emission and disposal of wastes [20]. The aim of the CE is to close the loop of the existing linear systems of consumption where the extracted resources after being processed to finished products become waste. The closed system of circular economy essentially reuse the resources and preserves energy [21]. This is even more relevant for situations where resources are less abundant and inaccessible [22,23]. The benefits include reduced effect on the environment like reduced pollution, reuse of wastes, recycling of components and remanufacturing. The CE approach also encourages consumers and manufacturers towards a more sustainable behaviour pattern [24–26]. This often works as a helpful tool for policymakers. Hence the importance of CE lies both in governance [27] as well as environmental psychology [28]. Thus, it is suggested that the organisations should shift their business models so as to the dependence on virgin raw materials and non-renewable energy sources is reduced, sustainable production practices is increased and sustainable strategies in value chain is adopted.

III. METHODOLOGY

An extensive review of literature was done for this paper. The author aims to extract a framework based on the existing literature for a circular model to be established in the textile and fashion sector. Literature review can be simply broken up into methodical identification of resources, effective research and analysis of documents containing information related to the research problem. In order to research for similar articles published recently in the last ten years in reputed journals, the author selected the traditional or narrative literature review process. The review was conducted specifically for studying articles related to the topic "Circular Models in Textile Sector". Articles and papers about sustainability, environmental impacts, alternative solutions, economic implications and the way forward was extensively read, reviewed and analysed. The research on keywords Circular Economy, Circular Textile, Linear Model, Industrial Ecology, Sustainable Business Model, Recycling, Waste Management etc, produced over 3000 papers and articles. The narrative literature review process provided a concrete guideline that helped the author in filtering the information systematically and designing a contribution focused review.

The information on "Circular Models in Textile Sector" was obtained from keywords search on Google Scholar, Shodh Ganga, Google books, Academia.edu, Researchgate. These literatures were accessed till November 2020. This literature collected was then collated and reviewed extensively and further analysed for proof and authenticity in case of ambiguity. The research databases used were Proquest, Jstor, Science Direct, EBSCO, Springerlink, Scopus and ABDC journal list. The search filters used were in the following sequence. (a) Scholarly peer-reviewed journal, (b) Year of search from 2010-2020, (c) Language chosen was English, (d) Source types- academic journals, (e) Subject: Thesarus term, (f) all databases. The use of such filters in EBSCO host provided 1369 articles from which only 12 relevant articles were selected. In the same process, articles obtained from Science direct were 595 out of which only 17 papers were listed. The initial number of articles shown on Proquest using the above keywords was 28,503 which reduced with each filter to provide only 19 relevant articles. Similarly, from Jstor only 10 relevant articles were selected, Spingerlink provided 9 articles and Scopus retrieved 8 relevant papers. Some articles obtained from different sources were removed from the list. The selected the period of search from 2010-2023 as the latest development in this particular area had to be explored.

IV. FRAMEWORK FOR TEXTILE SECTOR FOR A TRANSITION TO CE

The existing literature clearly indicates the need to the transition from the conventional LE to a CE. This is even more important in case of textiles industry. The existing textile and apparel industry is the second largest polluting industry across the world. The report by Ellen MacArthur Foundation lays a ground work on the transition to the Circular Model of economy for the textile sector [19]. This new economy is said to achieve the triple bottom line approach towards sustainability, with benefits towards economy, environment and society. This transition can be done through four distinct phases as shown in the Fig 1 below.

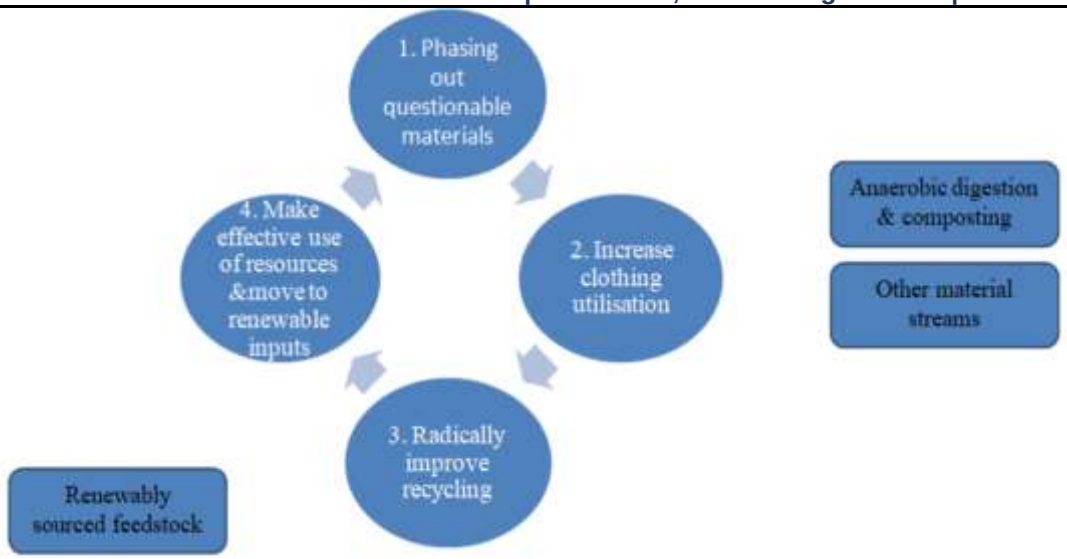

Figure 1. The new economy model adapted from "Ellen MacArthur" report on "A New Textiles Economy"[19]

4.1 Phasing out questionable materials

This model is primarily based on the material input. It is important that the material input is not toxic, so that while cycling it in the system no adverse impact occurs at any stage. This phasing out is done through two stages as shown in Fig 2. The first stage is to align the industry efforts across all stakeholders so that innovation is done for safe material cycles. The second stage is the development of new materials and processes to reduce the plastic microfibre release. This stage also deals with advancing the technologies to capture the microfibres released.

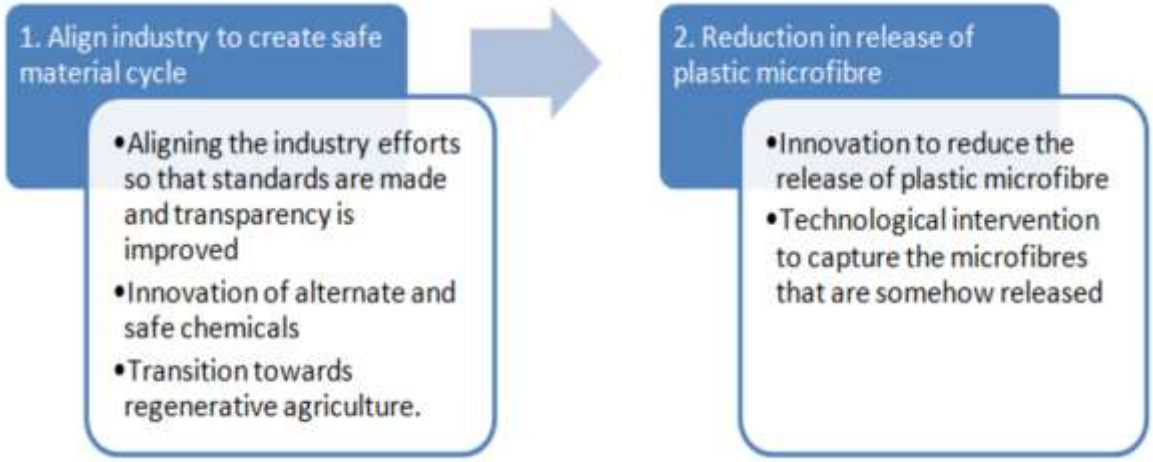

Figure 2: Stages of Phase I of the new economy model adapted from "Ellen MacArthur" report on "A New Textiles Economy" [19]

Align industry to create safe material cycle

The first stage of action to align the industry efforts can start from adoption of the RSLs or the "Restrictive substances lists", MRSLs or "Manufacturing restricted substances lists" and voluntary standards. The transparency in the supply chain has to be improved to make better sourcing decisions. This will reduce the usage of the polluting substances. Alternative and non-toxic processes need to be innovated. A number of brands have recognized their own set of RSLs [29]. MRSL contains chemicals which cannot be used above specific concentrations across the manufacturing process. Setting a standard for RSL and MRSL can simplify the process for the manufacturers. The smaller brands will also benefit from this as the manufacturer will retain the same standard. The lists will also help the brands in sourcing decisions in choosing safe chemicals. This will also increase the demand of the non-toxic alternative chemicals. Innovation is required to fill the gaps to provide the desired functionality.

Current policies do not regulate suppliers to specify chemical compositions of dyes. According to a 2016 report, 30% of chemicals used in textile manufacturing were listed a confidential [30]. However, the increased consumer awareness is changing the behaviour of the brands so as to reduce risk in reputation.

Policies and regulations can enforce best practices throughout the supply chain. This will also reduce the exposure to toxic chemicals [31].

The transition needs development of alternative safe chemicals and innovation in processes and practices. Brands are partnering with chemical producers who are innovating on safe chemicals [32]. Collaboration between all stakeholders is required for the same and can drastically reduce the usage of hazardous chemicals. Innovation is required in areas which provide functionality like replacing the use of formaldehyde for antiwrinkle finish. Innovation in dyeing process is also required.

Opportunity and potential also lies in the regenerative agriculture methods. These methods include organic farming, no tilling and restorative grazing [33]. These methods increase the soil fertility and profitability maintaining the natural ecosystem [34].

Reduction in release of plastic microfibre

The washing phase of plastic-based fabrics, like polyester, nylon and acrylic, releases a huge volume of microfibres that adversely impacts the environment [35]. Studies show that 35% of microplastics found in oceans are from textile washing [36]. Estimates indicate this volume to be 1.4 quadrillion [37]. The traditional effluent treatment system leaks up to 40% of microplastics [35]. The growing awareness and slow progress to address this area leads to a reputational risk of brands. A clear gap lies in identifying better solution specifically in the outdoor apparel industry, where the main fabric is synthetic.

For the transition, two distinct steps have been identified. These are the process innovation to reduce the release of plastic microfibre and technological intervention to capture the microfibres that are somehow released. To reduce the microfibre shedding, alternative materials need to be explored. Studies have shown that the factors affecting the microfibre shedding are washing method and type of fabric [38]. Reports show that reduction in brushing technique which is used in production of fleece can reduce the release [39]. This can be further reduced by replacing conventional cutting by laser cutting [39]. The special characteristics incorporated during the production can increase the shedding. Innovation is specifically sought in fabrics like fleece which accounts for most of the shedding. A major gap lies in this area with scope of material and process innovation.

Despite the redesigning solutions, capturing the microplastics leaked into the environment will be needed to be captured. Guppy Friend and CoraBall has created laundry accessory to address this concern [40,41]. Wexco has also developed a washing machine filter designed to capture the microplastics [42]. Effluent treatment plants are important in this aspect. However, even the advanced plants can capture of 90% of the release.

4.2 Change in apparel product development and usage pattern to reduce obsolescence

This section focuses on high quality clothing designs and production and identifying business model that can give access to these garments. Together these techniques can help in reducing the disposable nature of apparels. Doubling the number of times a garment is worn can reduce the greenhouse gas emission by 44% [19]. New business models are required for the transition from a linear model. The Ellen MacArthur Foundation identifies three distinct actions as depicted in Fig 3 that is required for this shift. These are scaling up rental services, enhance durability and brand policies towards increased utilisation.

Figure 3: Stages of Phase II of the new economy model adapted from “Ellen MacArthur” report on “A New Textiles Economy” [19]

Scaling up rental services

Rental models are ideal for segments as surveys shows that 26% of UK consumers dispose of clothes as they do not like it [43]. The same report indicates that 42% of clothes are disposed due to fitting issues. The rental model can also address this issue. The subscription models can be beneficial for the consumer to loan out a specific number of apparels against a monthly payment scheme, allowing them to have frequent change of clothes. The online shopping experience can also be attractive for the modern consumers. The model can be cost effective a compared to buying experience. Brands like Le Tote, Gwynnie Bee, Kleiderei, and YCloset have already ventured in this segment [44]. Rent the Runway has also been successful with their rental model for occasion wears [45,46]. These models can provide exposure to the brands and help make a better consumer loyalty and consistent revenue. French Connection has collaborated with Le Tote to make better sizing system and enhanced durability [44]. Ycloset have been successful in China since their launch in 2015 with the target of the mid-market segment. The model is comparatively new and consumers are still sceptical about it. The rental models can also be beneficial where the size varies over time. This segment includes infant and kids' wear as well as maternity apparels. As the ownership is retained with the brand, the clothing can be reused as the fitting period is very short. Opportunities also lie in the segment of luxury and sportswear. Rent the Runway has been successful in USA with renting over USD 800 million worth of apparels in 2014 [47]. The brand exclusively rents out occasion wear. Ms Paris, One More Closet and Dora's Dream rents out luxury apparels in China [19]. Houdini Sportswear is successfully renting out since 2013 at a rate of 10-25% of the retail price of the garment.

Logistics play a very important role is such a model as the movement of the products are more. The products will be returned to the store after use where quality checking has to be done. This will be followed by cleaning and re-dispatching. The key factors in logistics lies in cost, quality perseverance, information, convenience, appeal and speed. The logistics services can also be outsourced for ease of managing. The tracking of products with technologies such as RFID tagging is essential. It is also important to make sure that these codes are easy to scan and do not wear off. The logistics system can either take care of the pickup and drop services at customer doorsteps or offer the option for the customer pickup and drop. This can reduce the carbon emission from transportation of the garments.

Enhance durability

To make the rental model successful, it is important to make the garment durable. The enhanced durability can be achieved through use of high-quality materials. Durability is the unique selling point for certain clothing categories [48]. Patagonia, Levi's and Eileen Fisher business strategy revolve around durable and high-quality clothing. Labels that define durability will help the consumers to judge the quality and value of the product. Consistency of such labelling across the industry is also necessary. Long term rentals can be a potential in the segment of workwear and uniforms. The need of durability in workwear is very important as they are exposed to frequent washing. 90% of corporate clothes in UK is disposed at landfills or are incinerated [49]. With the ownership of these clothes retained with the brands in a long-term rental model, this concern can be addressed.

Customised manufacturing can increase the utilization of clothes. The consumer participation in the development or maintenance phase makes them more connected to the product. The customization is also supported by technological advancements for understanding body shapes and fits. Though the traditional made to measure clothing was replaced by ready to wears in most segments, 3D body scanning is paving the way back. This technology can scan the consumer and provide a perfect fit. This supply on demand model can reduce the need of discounts and clearance sales. Multifunctional designs, like reversible fabrics, removable panels etc, can also increase the apparel utilization.

Once the durability and quality standards will rise, the opportunity of resale will rise with it. Digitization has the potential to transform the traditional second-hand market to an organized online shopping experience. The resale model along with new collections can also be beneficial for the retailers in terms of low risk and high rewards. Maintenance and caring of clothes by user are also important to prolong the life of the apparels. Inclusions of proper care label in garments can make this process easier. A number of brands like Patagonia, Houdini, Salewa, Bergans etc, also offer in-store repairs [50].

Brand policies towards increased utilisation

Today's fast fashion culture manufactures apparel with low cost and minimal quality standards. This perspective has to change for the transition to the new model. The brands and retailers have to commit to the production of durable apparels as they are one with highest accountability for the impact of the sector. Reports indicate that the obsolescence factor of fashion is often introduced by brands [48]. To make the apparels durable the materials and trims used has to be of high quality, the construction and seams has to be stronger and the colourfastness of dyes and prints has to be more. Implementation of fair labour rights and use of non-hazardous materials across the supply chain is necessary. Guidelines laid by Higg index and Wrap Clothing Longevity Protocol helps the brands focus on durability (48,51). Regulations such as specifications of raw materials sourced, testing standards, and working conditions of suppliers can enhance this.

4.3 Improve Recycling

Using recycled materials instead of virgin feedstock will reduce the pressure on the environment. Coordination across the value chain through four distinct actions is required for this. These actions, as depicted in Fig 4, are designing products keeping in mind the need of recycling, technological intervention for increase of quality and economic viability of recycling, creating demand for recycled clothes and high scale clothing collection.

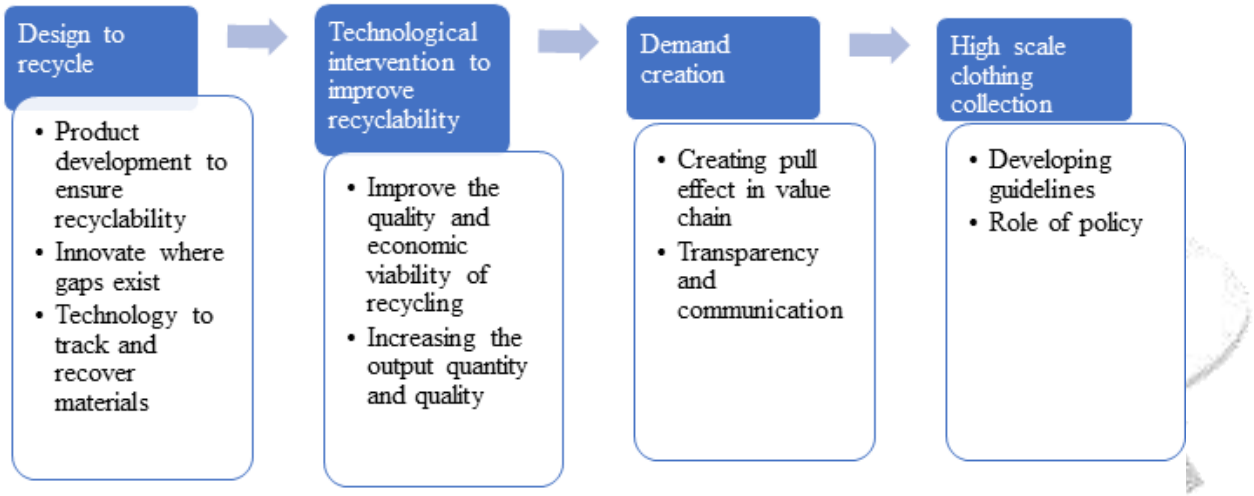

Figure 4: Stages of Phase III of the new economy model adapted from "Ellen MacArthur" report on "A New Textiles Economy" [19]

Design to recycle

To increase the recycling rate, it is important to detect and sort the materials. Labelling plays a very import role in this case. However, in many cases labels do not carry the correct information [52]. Wrong information and identification can disrupt the process of recycling. Materials or blend to enhance the functionality of garments should not hamper its recyclability. Coordination between the designers, buyers and suppliers to create and develop guidelines regarding the designs is important. Identification and classification of materials that are not recyclable is also important. The Fibersort project, run by experts across the textile value chain, aims to report the material blend and its volumes used in apparels [53]. Scope for innovation for new materials also exists. Technological interventions that can automate the sorting process can scale up the process. The sorting can be more accurate if done digitally.

Technological intervention to improve recyclability

Technological intervention is required to improve the quality and economic viability of recycling. A bottleneck exists in the availability of recycled materials as compared to virgin feedstock. The recycling of fabrics from production offcuts is already there. Nurmi clothing, Ahlma, Looptworks and few other brands used end-bits of fabric lays to make garments. The lack of trims and seams makes it easy to recycle [54]. Lindex creates new collections from denim garments of last season that were not sold [55]. Though the volume of fabric required for large scale production is difficult to source from recycled materials, the demand is present in bespoke designer wears.

Recycling yarns can be simpler, but very few fabrics are made from single yarn. 3D knitting and automation can address this concern. Benetton has designed a knitwear using a 450 mtrs long yarn in a

Japanese knitting machine [56]. HilaturasFerre develops yarn with 90% recycled cotton [57]. The recycled wool usage is already prevalent that is cost effective [58].

The automated tracking and tracing can speed up the sorting process. Technologies using Near Infrared Technologies or NIR can sort the apparels by material and colour. These can sort at a speed of one garment per second. FIBERSORT can sort garments according to colour and material at a very high speed. The Resyntex project, funded by EU, aims to build a plant to sort, pre-treat and process textiles [59]. SIPTex is developing tests to automatically sort textiles according to materials and colours using NIR and VIS technologies [60].

Demand creation

Like other sectors, fashion industry also works on customer demand. The transition towards the circular model can speed up by increasing the demand. Commitment of brands to use recycled materials instead of virgin feedstock can stimulate the pull effect in the supply chain. In short term this may be more expensive as the technologies are still in the development stage. However, the demand can motivation innovation and scale up the economies. Brands are already responding to this. 64 fashion companies have signed the Global Fashion Agenda's move toward circularity. These companies represent 7.5% of the apparel market share. One of the main point of the agenda is to increase the recycled material share [61].

Public procurement can help scaling up the collection. EUR 120 million is spent by the Dutch government annually for the procurement of workwear. In addition, the Circular Economy programme of Netherlands aims to reduce the raw materials use by 50% by 2030 [62]. Thus, government initiative along with public procurement can scale up the recycling sector.

Coordination between mills, brands and recyclers is important to maintain transparency and demand-supply match. This will also enhance the relationship and build trust in the supply chain. Online platform can be created for matching of the demand and the supply. This can bring together the buyers and suppliers in a common area. The brands can check the availability and quality of the recycled materials.

High scale clothing collection

The collection of old clothes has to be scaled up along with other technologies. Currently a number of collection systems exist, like municipal waste collection, kerbside collection, home pick-up, neighbourhood containers, retailer drop off, charity drop off etc. The rates and types of collection are different at different regions. UK and Germany offer choices of ways to dispose clothes. However, in most countries, this is done through the unorganised sector.

Pick up and drop off facilities at retailers, charities and municipality exists at some place, yet these needs scaling up. Patagonia, Zaraand H&M has their take back programmes. H&M targetsto collect 25,000 tons annually [63]. Technological intervention is required in collection along with sorting and recycling.

The unorganised collection system of the countries, where most of the after-use garments are shipped off, needs to be replaced by a formal system. Guidelines can be set to build the infrastructure for this scale up as well as implementation in countries where such systems do not exist. These guidelines can connect the collectors and sorters with the buyers, so that an uninterrupted supply chain is created.

4.4 Optimum resource utilisation and shift towards renewable sources

The new textiles economy model, as suggested in the Ellen McArthur Foundation report, needs to be based on renewable sources. This phase requires four distinct actions as depicted in Figure 5. These are incentivising good resource management, shifting to renewable virgin feedstock, scaling up efficient textile production and lesser resource utilization.

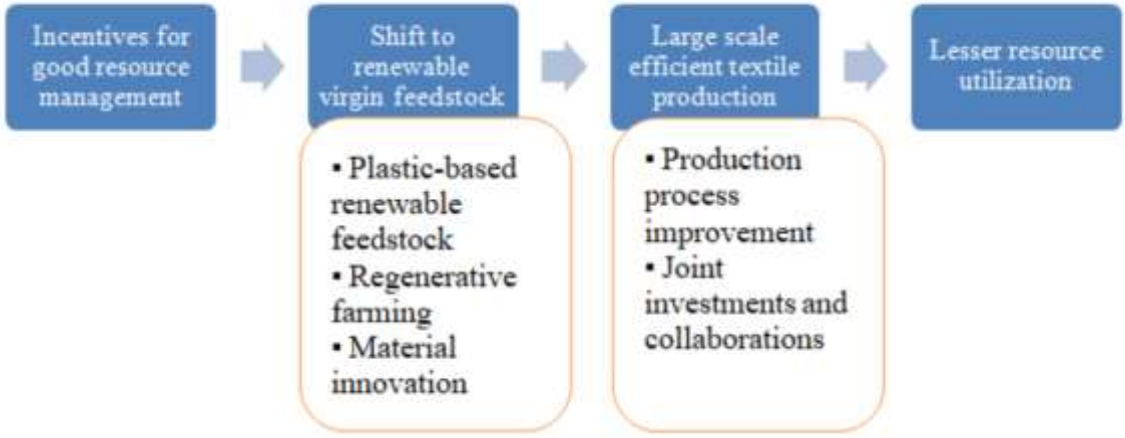

Figure 5: Stages of Phase IV of the new economy model adapted from "Ellen MacArthur" report on "A New Textiles Economy" [19]

Incentives for good resource management

The sourcing decisions of brands often impact the environment and the society. However, the cost associated with it is not taken into consideration. The cost of conventional cotton when calculated, considering its environmental and social impacts, will be seven times its current price [64]. Puma introduced an "Environmental Profit and Loss Methodology" in 2011 to increase the transparency in their production [65]. Such initiatives can help increase the knowledge base and understanding of the potentials and risks of different raw materials across the supply chain.

Shift to renewable virgin feedstock

The increase of recycled material utilization is required for the success of this model. However, demand of virgin feedstock will always be there. It has to be ensured that such inputs are derived from renewable resources. Plastic based feedstock can be made from sources like sugarcane, corn, waste vegetable oils, algae [66]. These will be biodegradable plastics that can address the concern of microfibre release.

Use of non-renewable sources can be reduced in the cotton farming and transition can be made to "regenerative agricultural practices". These practices do not use chemical pesticides and fertiliser. A number of innovations are being done in the research of new materials that fit in a circular model. Few of the examples include, Orange Fiber from orange juice by-products [67], QMILK from dairy leftovers [68], AgraLoop from agricultural waste [69], EcoAlf from coffee grounds [70] etc. Salvatore Ferragamo, an Italian couture brand, has already used Orange Fiber for their collection [67].

Large scale efficient textile production

To implement the new model across the supply chain, brands and retailer has to work in collaboration with their suppliers. Examples of reduction in resource utilization like water and energy already exist in the sector. However, due to lack of awareness and skills, these are not adopted at large scale. 10% to 20% of materials used in manufacturing are wasted due to offcuts. Other studies show that this percentage can increase up to 25-40% [71]. This is financially viable for both the buyers and manufacturers with the reduction of material wastes.

Efforts are also made toward reduction of usage of energy and water resources. Tools are applied in the production process to be more resource efficient and make their businesses more cost competitive [72]. Best practices across the textile industry for water and energy saving is listed by the National Resource Defence Council or NRDC [73]. The textile industry is majorly an unorganised sector with small and medium enterprises. It is difficult for these to have access to latest technology in terms of knowledge and cost. A number of online platforms like Euratex "Energy Made to Measure", make this information available for free [74].

The investments and costs involved in the technological interventions are often difficult for small scale manufacturers. The paybacks from such systems are long term and brands need to work together with the producers for implementations. The long-term benefits will include profits from reduced resource usage to both the parties.

Lesser resource utilization

The changes in the production process can reduce the use of toxic chemicals, non-renewable energy and water. The chemicals currently used in the production process are rarely retained and are discharged in the form of wastes leading to pollution. The waste generated will also be less in the new processes and thus capturing more value. Several innovations are carried out in the industry. The viscose production process requires solvents that are toxic without effluent treatment [75]. This process can be replaced by the lyocell production, where these solvents can be recovered up to 99.5%.

The usage of water in cotton cultivation can be reduced by shifting to areas that are rain fed and thus reducing the cost of irrigation [38,76]. Hugh volume of water is also used in the dyeing and finishing process. Technologies involving reuse of water and mechanisation can reduce this usage. Low or zero water processes are innovated in the area of dyeing. Adoption of these systems by bigger brands can make it more popular and thus reduce the cost.

V. CONCLUSION

It is evident from the literature reviewed that the linear model of economy in the textile sector is approaching obsolescence. A number of factors like fast fashion, consumerism, shorter product life, low quality and prices, increasing global population etc have contributed to this. This has increased the demand of cheap textile and apparel products, which in turn increased the volume of textile waste and disposal costs. More and more brands and organizations are shifting towards the circular model through digitalization, increased transparency and adopting new business models that are based on shared economy. This shift is accompanied with a number of challenges that are discussed in this literature review. Thought the challenges like waste management, product design and change in business models has barriers, it also comes with numerous opportunities. The concept of circularity origins in history and philosophy. The notion of giving back to the system is very old and is present in a number of philosophical school of thoughts. The current technological advances and digitalization has to scope to support the shift of the linear model to a circular economy.

REFERENCES

[1]Ellen MacArthur Foundation. Towards the Circular Economy : Accelerating the scale-up across global supply chains. World Economic Forum. 2014.

[2]Boiten VJ, Han SL-C, Tyler D. Circular economy stakeholder perspectives: Textile collection strategies to support material circularity. Resyntex [Internet]. 2017; Available from: http://www.resyntex.eu/images/downloads/ValrieJBoiten_Textile_collection_strategies.pdf

[3]Prieto-Sandoval V, Jaca C, Ormazabal M. Towards a consensus on the circular economy. J Clean Prod. 2018;179:605–15.

[4]Walter L. Towards a 4 th Industrial Revolution of Textiles and Clothing - A Strategic Innovation and Research Agenda for the european Textile and Clothing Industry. Eur Technol Platf. 2016;(October):23.

[5]EURATEX. Key Figures 2017 - The EU-28 Textile and Clothing Industry in the year 2017. 2018;

[6]Resta B, Gaiardelli P, Pinto R, Dotti S. Enhancing environmental management in the textile sector: An Organisational-Life Cycle Assessment approach. J Clean Prod [Internet]. 2016;135:620–32. Available from: http://dx.doi.org/10.1016/j.jclepro.2016.06.135

[7]Koszewska MG. The Ecological and Ethical Consumption Development Prospects in Poland Compared with the Western European Countries. Comp Econ Res. 2011;14(2):101–23.

[8]Wyman O. Fast Fashion strategy on-trend with a new style of supply chain. 2015;8. Available from: http://www.oliverwyman.com/content/dam/oliver-wyman/global/en/2015/aug/2015_OliverWyman_Fast_Fashion_screen.pdf

[9]Remy N, Speelman E, Swartz S. Style that's sustainable : A new fast-fashion formula. 2016;1–6.

[10] Dahlbo H, Aalto K, Eskelinen H, Salmenperä H. Increasing textile circulation—Consequences and requirements. Sustain Prod Consum [Internet]. 2017;9(March):44–57. Available from: http://dx.doi.org/10.1016/j.spc.2016.06.005

[11] Lewis TL, Park H, Netravali AN, Trejo HX. Closing the loop: a scalable zero-waste model for apparel reuse and recycling. Int J Fash Des Technol Educ [Internet]. 2017;10(3):353–62. Available from: http://dx.doi.org/10.1080/17543266.2016.1263364

[12] Claudio L. Waste Couture. Env Heal Perspect 2007 Sep; 2007;115(9):(Sept 2007):A449–A454.

[13] Payne A. Open-and closed-loop recycling of textile and apparel products [Internet]. Handbook of Life Cycle Assessment (LCA) of Textiles and Clothing. Elsevier Ltd; 2015. 103–123 p. Available from: http://dx.doi.org/10.1016/B978-0-08-100169-1.00006-X

[14] Koszewska M. Circular Economy - Challenges for the Textile and Clothing Industry. Autex Res J. 2018;18(4):337–47.

[15] Qin Y. Global Fibres Overview. Tecnon OrbiChem [Internet]. 2014;2014(May):27. Available from: http://www.orbichem.com/userfiles/APIC 2014/APIC2014_Yang_Qin.pdf

[16] Oerlikon. The Fiber Year 2015 : World Survey on Textiles & Nonwovens. 2015;(19).

[17] Vancouver Economic Commission. Towards the Circular Economy: Identifying local and regional government policies for developing a circular economy in the fashion and textiles sector in Vancouver, Canada. 2015;(September):98.

[18] Teunissen J, Zijverden M van. Fashion Data: On the Failing Fashion System and Alternative Solutions. 2016;1–8. Available from: http://ualresearchonline.arts.ac.uk/9743/6/Fashion Data_ On the Failing Fashion System and Alternative Solutions, José Teunissen.pdf

[19] Ellen MacArthur Foundation. A new textiles economy: Redesigning fashion's future. Ellen MacArthur Found [Internet]. 2017;1–150. Available from: https://www.ellenmacarthurfoundation.org/publications/a-new-textiles-economy-redesigning-fashions-future

[20] Lazarevic D, Valve H. Narrating expectations for the circular economy: Towards a common and contested European transition. Energy Res Soc Sci [Internet]. 2017;31(March 2020):60–9. Available from: http://dx.doi.org/10.1016/j.erss.2017.05.006

[21] Urbinati A, Chiaroni D, Chiesa V. Towards a new taxonomy of circular economy business models. J Clean Prod. 2017;168(i):487–98.

[22] The Centre for Sustainable Design. The journal of sustainable product design. 1998;(7).

[23] Ellen MacArthur Foundation. Why the circular economy matters. Deliv Circ Econ A Toolkit Policymakers. 2015;19–32.

[24] Murray A, Skene K, Haynes K. The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. J Bus Ethics. 2017;140(3):369–80.

[25] Miliute-Plepiene J, Plepys A. Does food sorting prevents and improves sorting of household waste? A case in Sweden. J Clean Prod [Internet]. 2015;101:182–92. Available from: http://dx.doi.org/10.1016/j.jclepro.2015.04.013

[26] Schneider A. Reflexivity in Sustainability Accounting and Management: Transcending the Economic Focus of Corporate Sustainability. J Bus Ethics. 2015;127(3):525–36.

[27] Haas W, Krausmann F, Wiedenhofer D, Heinz M. How circular is the global economy?: An assessment of material flows, waste production, and recycling in the European union and the world in 2005. J Ind Ecol. 2015;19(5):765–77.

[28] Gregson N, Crang M. From Waste to Resource: The Trade in Wastes and Global Recycling Economies. Annu Rev Environ Resour. 2015;40:151–76.

[29] Health and Safety Executive. What is REACH? Reach [Internet]. 2006;(June):6–7. Available from: http://www.hse.gov.uk/reach/whatisreach.htm

[30] Swedish Chemicals Agency. Hazardous chemical substances in textiles – proposals for risk management measures Report from a government assigment. 2016; Available from: http://www.kemi.se/global/rapporter/2016/report-8-16-hazardous-chemical-substances-in-textiles.pdf

[31] Reach T. Euratex calls for improvements to REACH restriction process. 2020;(February 2017):1–3.

[32] Mowbray J. Huntsman and Viyellatex enter collaboration. 2016;(December):2016.

[33] Ellen MacArthur Foundation. Achieving 'Growth' Within. Ellen MacArthur Found [Internet]. 2017;149. Available from: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Achieving-Growth-Within-20-01-17.pdf

[34] White C. Why Regenerative Agriculture? Am J Econ Sociol. 2020;79(3):799–812.

[35] Browne MA, Crump P, Niven SJ, Teuten E, Tonkin A, Galloway T, et al. Accumulation of microplastic on shorelines woldwide: Sources and sinks. Environ Sci Technol. 2011;45(21):9175–9.

[36] Boucher J, Friot D. Primary microplastics in the oceans [Internet]. 2017. 43 p. Available from: https://www.iucn.org/content/primary-microplastics-oceans

[37] Hodgson N. MICROFIBERS AND THE OUTDOOR INDUSTRY : 2020;1–5.

[38] Napper IE, Thompson RC. Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions. Mar Pollut Bull [Internet]. 2016;112(1–2):39–45. Available from: http://dx.doi.org/10.1016/j.marpolbul.2016.09.025

[39] Roos S, Arturin OL, Hanning A-C. Microplastics shedding from polyester fabrics. 2017;15. Available from: www.mistrafuturefashion.com
[40] GuppyFriend. GUPPYFRIEND WASHING BAG. 2020;1–5. Available from: http://repositorio.unan.edu.ni/2986/1/5624.pdf
[41] CoraBall. HUMAN-SCALE SOLUTION. 2020;1–6.
[42] Filter L, Filter FL, Cart FB, States U. Filtrol Lint Filter - with 1 Filter Bag. 2020;1–6.
[43] WRAP. Consumer clothing survey. 2019;3–5. Available from: http://www.wrap.org.uk/sustainable-textiles/scap/report/consumer-clothing-survey
[44] Businessweek B. Brick-and-Mortar Shops Bet on Startup Tech to Bring Back Customers. 2020;1–12.
[45] Kumar A, Killingsworth MA, Gilovich T. Waiting for Merlot: Anticipatory Consumption of Experiential and Material Purchases. Psychol Sci. 2014;25(10):1924–31.
[46] Morgan B. NOwnership, No Problem: An Updated Look At Why Millennials Value Experiences Over Owning Things. Forbes [Internet]. 2019;1. Available from: https://www.forbes.com/sites/blakemorgan/2019/01/02/nownership-no-problem-an-updated-look-at-why-millennials-value-experiences-over-owning-things/#27f742f6522f
[47] Vasan P. Rent the Runway's designer closet tops $800 million. WwwCnbcCom [Internet]. 2015;1–8. Available from: http://www.cnbc.com/2015/07/25/rent-the-runways-designer-closet-tops-800-million.html
[48] Cooper T, Claxton S, Hill H, Holbrook K, Hughes M, Oxborrow L. Clothing longevity protocol. 2014;(October 2012):1–11.
[49] Gracey F, Moon D. Valuing our Clothes: The Evidence Base. Waste Resour Action Program [Internet]. 2012;(July):71. Available from: http://www.wrap.org.uk/sites/files/wrap/10.7.12 VOC-FINAL.pdf
[50] Greenpeace International. Fashion at the Cross Roads. 2017;108. Available from: https://storage.googleapis.com/planet4-international-stateless/2017/09/76e05528-fashion-at-the-crossroads.pdf
[51] Sustainable Apparel Coalition. Higg Product Tools Make Better Choices at Every Stage of a Product ' s Development The Higg Materials Sustainability Index. 2020. p. 1–6.
[52] FTC. Fiber Content Statement. 2020 p. 1–4.
[53] Circle Economy. Fibersort. 2020. p. 1–4.
[54] Nurmi Clothing. Sustainability. 2020. p. 1–3.
[55] Lindex Group. Circular fashion - ScienceDirect. 2020;1–7. Available from: https://www.sciencedirect.com/science/article/pii/B9780081026304000029
[56] Brismar A. Introducing the concept " single-thread knitwear ". Green Strategy. 2020;1–5.
[57] Gmbh G. Certificate of compliance. Test. 2014;8(8):86842.
[58] Balli R, Welle D, Longo C. Italian fabric makers turn dirty secret into marketing weapon. 2020;11–2.
[59] Blanch-Perez-del-Notario C, Saeys W, Lambrechts A. Hyperspectral imaging for textile sorting in the visible-near infrared range. J Spectr Imaging. 2019;8:1–11.
[60] SYSAV. Textile sorting project Siptex nominated for fashion sustainability award. 2020;53–5.
[61] Watson D, Eder-Hansen J, Tarneberg S. A Call To Action for a Circular Fashion System. Glob Fash Agenda 2017 [Internet]. 2017;9. Available from: http://globalfashionagenda.com/wp-content/uploads/2017/04/GFA17_Call-to-action_Poluc-brief_FINAL_9May.pdf%0Ahttps://www.copenhagenfashionsummit.com/wp-content/uploads/2017/04/GFA17_Call-to-action_Poluc-brief_FINAL_9May.pdf
[62] Dutch Ministry of Infrastructure and the Environment. Sustainability criteria for Sustainable Public Procurement of Workwear version 1.3. 2011;(October):1–10. Available from: https://english.rvo.nl/sites/default/files/2013/12/Criteriadocument Workwear.pdf
[63] H&M. HM Charity Star. 2019.
[64] Grosscurt C, de Groot Ruiz A, Fobelets V. The True Price of Cotton from India. 2016;1–35.
[65] Puma. PUMA ' S EP & L. 2020. p. 1–5.
[66] The New Plastics Economy. Ellen MacArthur Foundation. 2006.
[67] Orange Fiber. SUSTAINABLE FABRICS FROM CITRUS JUICE BY-PRODUCTS. 2020. p. 1–6.
[68] Qmilk. Our unique and innovative products Qmilk Faser. 2020. p. 1–8.
[69] Sustainable Brands. Plug and Play Accelerator Reveals 12 New Startups Changing the Face of Fashion. 2020;2–5.

[70] EcoAlf. EcoAlf Recycled Materials. Austroads. 2009. p. 1–5.
[71] Runnel A, Raihan K, Castle N, Oja D, Bhuiya H. The Undiscovered Business Potential of Production Leftovers within Global Fashion Supply Chains: Creating a Digitally Enhanced Circular Economy. Reverse Resour [Internet]. 2017;1–32. Available from: https://www.reverseresources.net/about/white-paper
[72] Kerr J, Landry J. Pulse of the. Glob Fash Agenda Bost Consult Gr [Internet]. 2017;11. Available from: http://globalfashionagenda.com/wp-content/uploads/2017/05/Pulse-of-the-Fashion-Industry_2017.pdf
[73] Greer AL, Keane SE, Lin Z. NRDC ' s Ten Best Practices for Textile Mills to Save Money and Reduce Pollution. NRDC Clean By Des. 2010;(February).
[74] Intelligent Energy Europe Programme of the EU. Energy Distribution Support Tool EDST. 2020.
[75] CleanByDesign. What are the Heavy Impacts of Fiber Production? 2012;(April). Available from: www.cleanbydesign.org
[76] Sustainable T, Group B. GLASA 2015 Apparel Sector Water Report and nalists announced. 2020;1–4.