An aerial photograph of the ocean with white-capped waves. The text is overlaid in a bold, hand-drawn style. The first line is white, and the rest are black.

IS FRESHWATER
SCARCITY GOING
TO INFLUENCE
THE DEVELOPMENT
OF NATURAL AND
SUSTAINABLE
FABRICS?

Is freshwater scarcity going to influence the development of natural and sustainable fabrics?

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Sheffield Hallam University

The candidate confirms that the work submitted is their own and that appropriate credit has been given where reference has been made to the work of others.

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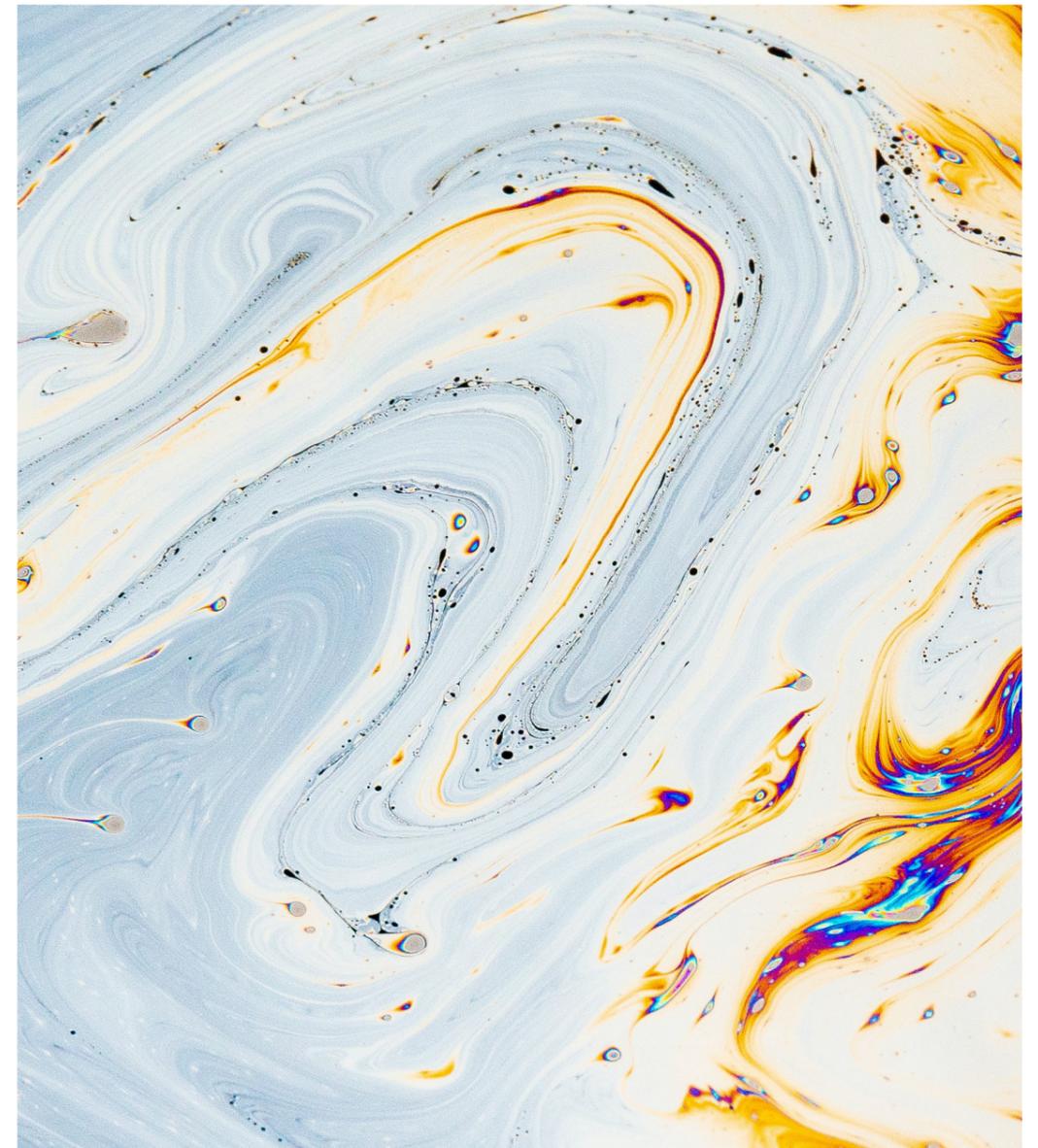
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to

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A close-up photograph of a person's hand, wearing a dark sleeve, reaching down towards a body of water. The hand is open, with fingers slightly curled, and its reflection is visible in the rippling water below. The background is a soft, out-of-focus blue-grey, suggesting a natural outdoor setting. A thin orange horizontal line runs across the middle of the image, separating the visual from the text.

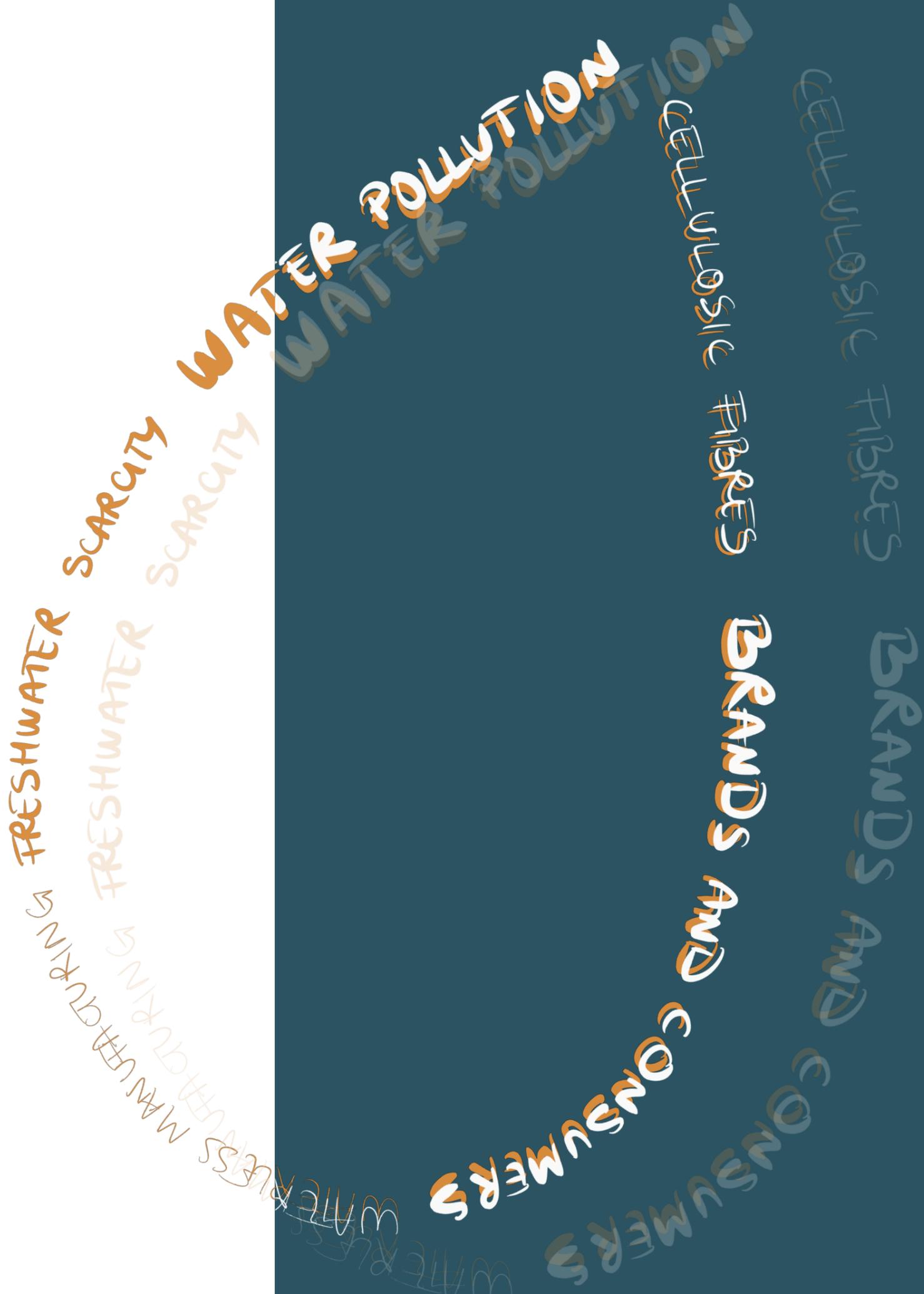
abstract

Water scarcity is potentially becoming a major threat not only to the fashion sector, but to society and life itself. The negative impact of using vast amounts of freshwater for garment manufacturing purposes on the environment and communities is not currently being addressed with a sense of urgency by most fashion retailers. This increasingly pressing issue is undoubtedly shaping consumer opinions and prompting many companies to invest in more freshwater-efficient manufacturing processes.

A mix of both primary and secondary research will be used to shape this dissertation paper. Primary research carried out in the support of this essay will include interviews with both consumers and professionals, online surveys, as well as digital focus groups that aim to better understand the role of brands and consumers in the future development of freshwater-free textiles, market share and manufacturing methods. Furthermore, secondary research will be compiled from a range of reliably sourced articles, journals, studies and books that discuss the issues and solutions associated with water use in the apparel industry. Key aspects uncovered during the research intend to support the argument that water stress is increasingly influencing the idea of eliminating the use of freshwater from the production process of garments. The paper is also going to take counter arguments into consideration, to present different perspectives surrounding this complex issue.

To conclude, the research will clearly evidence that conventional methods used in the farming of water-intensive raw materials and garment manufacturing negatively impact the environment and water-stressed regions around the globe. From raw material to finished product, the issue of freshwater scarcity is increasingly influencing brands, as well as consumers, and will have an ever-growing impact on the development of modern and water-efficient textile manufacturing methods.

FIVE KEY WORDS



methodology

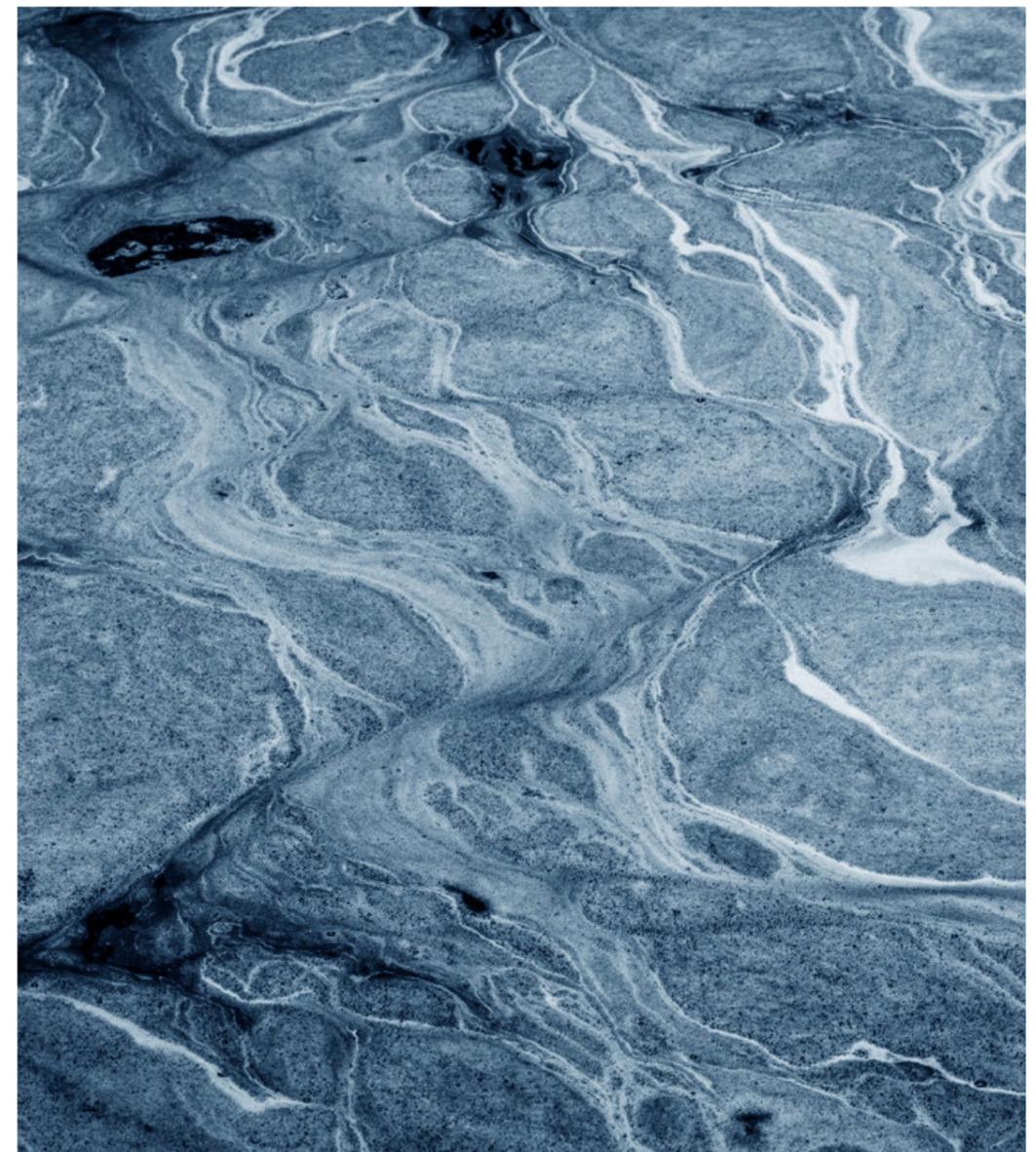
Ecological and ethical issues regarding water use for garment production and manufacturing in the fashion industry will be the main focus of this dissertation. Nowadays, unsustainable amounts of essential freshwater resources are being used for cultivating cotton crops and textile finishing stages. Through secondary research compiled from reliable publications and online resources, as well as primary quantitative and qualitative research, the study shapes a solid image of the current situation regarding the water footprint (WF) of textiles and future freshwater-free technologies.

In order to solidify the argument, chapters have been structured based on key findings and critical areas. Using the WF model and quantitative secondary data, the initial chapter will uncover the concept of freshwater scarcity and highlight in what manner fashion is contributing to this globally pressing issue. Water-efficient textiles commercially available will be discussed throughout a second chapter, highlighting key water-related aspects in the production process of these fabrics. Moreover, the dynamic between brands and consumers, as well as their essential role in driving change, will be thoroughly analysed as part of a third chapter. Finally, a fourth section intends to discuss the prospect of a freshwater-free industry, thoroughly analysing the latest technological discoveries and projects from a critical point of view. This paper aims to focus on the risks associated with inefficient use of water resources for raw materials production and fabric finishing, while investigating the ways in which fashion can tackle this problem now and in the future. To correctly answer the question of this dissertation, appropriate methods have been established to create a valid and effective argument. Quantitative data from reliable and diverse secondary resources will be used to highlight the increasing amount of freshwater resources used for textile production globally. The research will focus on academic journals written by reputable scholars who conducted extensive studies regarding global use of water resources for specific agricultural purposes, as well as statistics from online resources such as The Water Footprint Network and Common Objective. Moreover, industry reports from Textile Exchange

and Global Fashion Agenda have also been analysed to shape a coherent image of the industry impact on water resources, future trends in terms of natural textiles and the role of brands in finding new, innovative solutions to curb the negative impacts of this issue. Primary questionnaires will be distributed using digital platforms and completed by consumers representing Generation Z and young Millennials. These will comprise a series of Yes/No questions which also allow respondents to give more elaborate answers. They will be thoroughly analysed in order to extract the most relevant trends, as well as individual opinions regarding current use of water resources and the role of brands in creating a freshwater-free industry.

Qualitative data will be compiled using 10-question interviews and a focus group conducted digitally via Email or social networking platforms with consumers interested in sustainable fashion. This method allows the participants time to answer and expand on their opinions as much as they feel necessary. The questions will be structured to determine brand preferences and whether this particular consumers' group will influence the demand for freshwater-efficient textiles. Furthermore, interviews with industry professionals working for companies aiming to reduce the WF of the apparel industry will help paint a clear picture of natural textile production in the future. Their dedication towards developing cutting-edge technologies that eliminate the need for using extensive water resources during the production process is relevant in understanding how sustainability standards will change. In addition, relevant books discussing the impact of growing thirsty crops like cotton on natural resources such as "Organic Cotton: Is it a sustainable solution?" and other online articles from established news sources will be scrutinized to build a solid rationale regarding the future of cellulosic textiles.

Using a holistic research approach by analysing both consumer and professional opinions, as well as quantitative data from experts with regards to this subject is crucial in creating a valid argument throughout the dissertation paper.



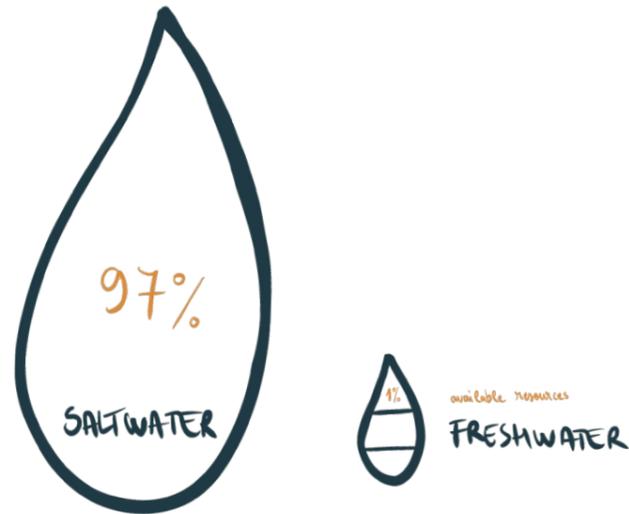
chapter 1

Fashion is a thirsty industry

The fashion industry has always played an important part in the cultural development of society, influencing key aspects of world politics, economy and social change. Garments and fabrics touch everyone's lives, but they also have a great impact on natural resources and ecosystems.

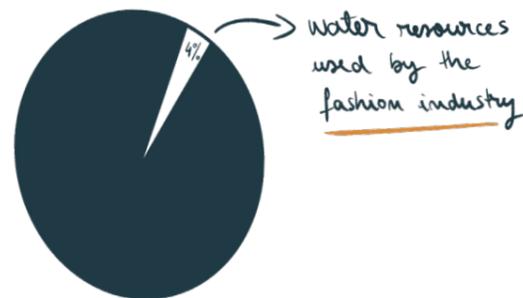
From the early stages of raw materials production to manufacturing and finishing processes, the industry requires high volumes of freshwater. According to the "Pulse Fashion Report" 2017, the apparel industry consumes 79 billion m3 of water per year, an amount that is set to increase twofold by 2030 (Eder-Hansen et al., 2017). Comparing data shows that this volume represents almost 2% of the total freshwater withdrawal globally, and accounts for more than ten percent of the water resources used in all types of industries (Common Objective, 2018). In a 2017 report by the Ellen McArthur Foundation, an even greater amount is being mentioned, namely an average of 100 billion m3 of water per year, or 4% of the total clean water extracted at a global level (Herrmann, 2017). Throughout the natural fibre production chain, one can identify two significant stages: the agricultural phase, and industrial one (Chapagain, Hoekstra, Savenije & Gautam, 2006). In terms of production, comparing cotton to other natural fibre crops like hemp, kenaf or jute clearly reveals its thirsty nature. This is due to the substantial amount of irrigation needed for the plant to reach the harvesting stage, requiring an average of 14,000 L/kg to grow (Gardetti & Muthu, 2019). Despite this increased amount needed to grow cotton crops, this raw material makes up 90% of the entire natural fibres market, being present in 40% of all garments produced globally (Ravasio, 2012).

Water resources accessible to humans may seem abundant, yet 97% of all water on Earth is represented by oceans, while only 3% is considered freshwater. Out of this limited supply, 2 thirds are trapped in glaciers, ice sheets or deep below ground. This means that all living beings remain reliant on a mere 1% of all water



Only 1 percent of our freshwater is easily accessible to humans

Table 1, Total water available globally, 2014



The fashion industry uses 4% of total the freshwater extracted at a global level

Table 2, Fashion industry water consumption globally, 2017





resources available (Sharghi, 2014). Due to this limited availability, using freshwater efficiently has become a crucial aspect for the sustainable development of society. The WF is a concept coined by Hoekstra and Hung (2002) and further developed by Chapagain and Hoekstra (2004), gauging the amount of water utilised in the manufacturing of products and services. It can be used to measure the impact of an entire activity, such as cultivating cotton, or only the final outcome, such as a pair of jeans, by assessing both consumption and contamination throughout all stages in the chain of production (Water Footprint Network, 2020). Using this method, several research papers attempted to measure the impact brought by cotton consumption on water resources. Early reports describe the total WF of cotton as an average of 43 m³/year per person or the equivalent of 2.6% of the entire water consumption globally (Chapagain et al., 2006). More recent academic studies estimate the yearly global WF associated with the consumption of cotton goods at a lower value, namely almost 33 m³/year per capita or approximately 238 full bathtubs of water for each person every year (Mekonnen & Hoekstra, 2010). Furthermore, out of the total amount of water used for growing cotton crops, 39% has been identified as being blue water (irrigation water sourced from either the surface or groundwater resources), which makes cotton the second most water-intensive crop in terms of irrigated water use at a global level (Siebert & Döll, 2010). Unsustainable irrigation practices occur when water usage goes beyond the limit of renewability of local water sources. These economical activities have a detrimental effect on the environment, depleting groundwater resources and causing ecological degradation. Today, one third of unsustainable water consumption related to global crop trade is caused by cotton (Rosa, Chiarelli, Tu, Rulli & D'Odorico, 2019). Another study discussing the sustainability of irrigated crops, highlights that 57% of the blue WF globally is unsustainable, and almost 70% of this amount is caused by just five crops, cotton accounting for a tenth. Moreover, 50% of the unsustainable blue water consumption related to cotton is exacerbating water scarcity in certain river basins around the

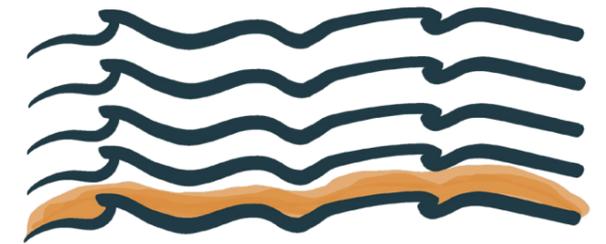
world, where almost 319 million people have to face severe water shortages some time throughout the year (Mekonnen & Hoekstra, 2020). Currently, almost 500 million people worldwide endure extreme water shortages throughout the entire year, while around 4 million have to cope under extreme water stress for at least a month (Safaya, Zhang & Mathews, 2016). Thus, in their 2016 annual risks report, the World Economic Forum catalogued unsuccessful global warming reduction and adjustment as the highest threat globally with regards to potential impact, mentioning water crises and large-scale involuntarily migrations among the most likely repercussions (World Economic Forum, 2016). As more than half of the total water used for irrigation purposes comes from the surface (Siebert et al., 2010), one can observe a direct link between agricultural production and water flow depletion (Richter, 2014). A very famous example that illustrates the environmental effects of using surface water for irrigation, especially in drier regions, is the Aral Sea case. Due to excessive water abstractions for the irrigation of cotton crops between 1960-2000, the Aral Sea shrank about 80% in volume and 60% in surface (Chapagain, Hoekstra, Savenije & Gautam, 2005). However, cotton is still considered the most practical of all natural fibres. It possesses great qualities like comfort, durability and moisture absorption, allowing the skin to breathe. In addition, depending on the processing method it also has both cooling and warming abilities, which makes it an appropriate choice throughout all seasons (Hallett & Johnston, 2014).

Even if cotton farming is largely considered the most water-intensive process in the apparel industry, the relationship between fashion and water involves more than just growing cotton crops. Besides from the natural water resources depletion previously discussed, water contamination is another negative effect worth mentioning. The pesticides, fertilisers and minerals used on cotton plantations contaminate local waterways, wetlands and aquifers, negatively impacting human health and biodiversity (WWF, 2020). It is estimated that the manufacturing phase represents almost 15%



of a fashion retailer's WF, and the conversion of raw material into fabric involves approximately 8,000 synthetic substances worldwide (Ravasio, 2012). Chemical processing (bleaching, dyeing, finishing etc.) is considered highly water-intensive as most dyes and chemicals are only transferred to textiles using aqueous solutions (Samanta, Pandit, Samanta & Basak, 2019). Such processes and treatments contribute to almost 20% of the total industrial water pollution globally (The World Bank, 2019), and estimations show that each kg of cotton can require up to 125 L of water for dyeing and finishing. If this untreated wastewater, also known as grey water, is discarded into water sources used for drinking, bathing or fishing, toxic chemicals can disrupt local ecosystems and have a detrimental effect on human health (Herrmann, 2017).

However, in countries like India, the textile industry contributed 2% to the national GDP and 15% to all export earnings in the 2019 fiscal year. Cotton farming and textile processing offers employment opportunities for more than 45 million people (India Brand Equity Foundation, 2020), representing a major part of the Indian economy and the reality of those who need to expose themselves to provide for their families. Even if the industry offers direct employment to a large number of people worldwide, benefiting local communities through the creation of jobs, its environmentally damaging practices are taking a toll on textile workers and everyone living near polluted rivers. In India, where 600 million people suffer from acute water supply shortages (Yeung, 2019), 85% of the entire population's daily needs could be met only by using the amount of water going into the country's cotton growing industry (Leahy, 2015). Moreover, the



20% of the total industrial water pollution globally is caused by textile treatments

Table 3, Industrial water pollution, 2019

“Water issues
 are global, but
 like politics,
 everything is local.”

artist Susan Knight for Smithsonian Mag

(Fessenden, 2016)

widespread discharge of untreated wastewater from textile factories has poisoned primary sources of freshwater to such an extent that some rivers in India, China and Bangladesh are considered biologically deceased, making near-by cities uninhabitable. Prolonged exposure to these highly toxic chemicals has been identified as the main cause for numerous and very serious medical conditions like loss of sensory adaptation, gastric problems, cancer and even bone deformation (RiverBlue, 2018). Apart from the social and environmental impact of water pollution, increasing freshwater scarcity is also threatening the global economy. In a World Wildlife Fund (WWF) analysis, 58% of the entire cotton production globally is located in regions where operations are at a high-risk of being affected by lack of physical water resources (Petrie, 2019), while a 2015 survey conducted by the World Economic Forum, also acknowledges water crises as the highest threat to global economy disruption (Safaya et al., 2016).

chapter II

Current water efficient fabrics

This section will examine current water-efficient textiles of botanical origin from a water usage point of view. The role of fibres such as organic cotton, Tencel/Lyocell or recycled man-made cellulosic fibres (MMCFs) will be discussed in relation with the future development of the textile industry. As the world population is on a rising trend, estimated to reach between 9.4 and 10.2 billion by 2050, global freshwater availability is subsequently predicted to decrease due to appropriation and pollution of natural resources (Boretti & Rosa, 2019). Thus, access to freshwater resources will become ever more difficult, while demand for water-efficient textiles will increase (Ravasio, 2012).

In recent years, many associations and sustainability-focused initiatives such as Cotton made in Africa (CmiA) and Better Cotton Initiative (BCI) have brought a positive impact on the water resources consumption and administration in the fashion industry (Lernoud et al., 2017). Cotton is certified organic when the farming process does not involve synthetic chemicals and also considers soil health, human wellbeing and ecosystem conservation (Kooistra, 2006). From a water-usage point of view, organic cotton is mostly rain-fed, which means that the amount of irrigation water used is considerably low compared to conventional cotton, with 182 L/kg and 2,120 L/kg respectively (Textile Exchange, 2014). Using a lower amount of blue water for crop cultivation is an essential aspect in protecting surface and groundwater resources, especially in already water-stressed regions. However, farming only represents one of the stages in apparel manufacturing and, even if the raw material has an organic certification, it can still be processed using conventional methods, which results in the discharge of hazardous wastewater into local waterways and aquatic systems. Garments should be certified as fully organic to ensure that water resources, human and environmental health have been taken into account during all stages of the process (Rieple & Singh, 2010). Moreover, a recent study focusing on water savings through non-governmental incentives highlighted that in certain situations such as a pest outbreak,

farmers need to use chemical methods to protect their harvest or risk losing the entire crop. Those interviewed as part of the study revealed they would use pesticides even with the risk of losing their organic certification, which demonstrates the inevitable risk of water pollution from agricultural runoff (Kemper & Partzsch, 2019).

Similarly to organic cotton, cellulose-based Lyocell fibre production mainly relies on green water (water from precipitation consumed by evapotranspiration in forests, crop lands etc), which usually means a reduced footprint on freshwater resources. Regarding green, blue and grey water consumption, lyocell fibres need an average of 1384, 34.5, and 35.3 m³/t, as opposed to 263, 2767, and 203 m³/t for conventional cotton (Chico, Aldaya & Garrido, 2013). Manufactured by Austrian company Lenzing, TENCEL™ Lyocell and Modal fibres are certified biobased fibres, fully compostable and biodegradable, produced in a closed-loop process that recycles water and has a solvent-recovery rate higher than 99% (Tencel, 2020). Compared to cotton fibre production, TENCEL™ uses almost 20 times less water, as the raw material involved, namely wood pulp, does not require any irrigation during the farming stage (Ellen McArthur foundation, 2020, 29:08). However, some authors discuss the strong connection between the land surface used for agriculture and green water consumption in water supply management, recommending a direct link between land management policies and water planning (Jewitt, 2006). Throughout the global hydrological cycle and water distribution, green water represents 65% of the total annual precipitation, while blue water only constitutes 35%. Current climate instability and changes in water use can have a great impact on the entire hydrological system, particularly green water resources reaching catchment basins (Lyu, Wang, Sun, Ren & Zheng, 2019). Even so, Lyocell is widely considered to be a viable substitute to cotton fibres thanks to its similar properties (Chhabra, 2016), and also constituted the third most popular MMCF after viscose and rayon, having a market share of about 4.3% of all MMCFs. Compared to other fibres in the same category, Lyocell's compound annual growth rate from

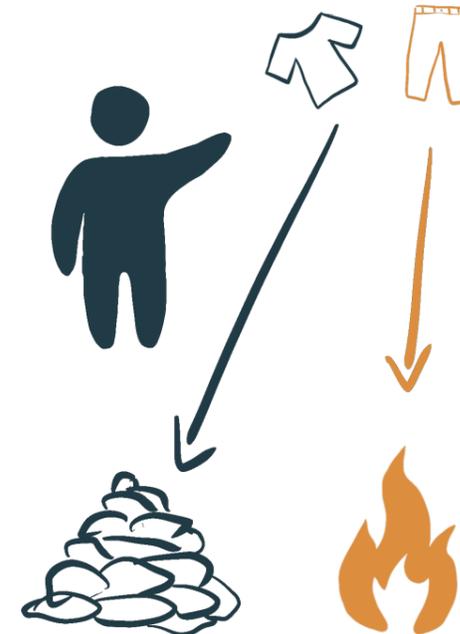


TENCEL

COTTON

On average, Tencel production uses 20 times less water than conventional cotton

Table 4, Tencel Water Consumption, 2020



95% of the post-consumer cotton textiles are sent to incineration facilities or landfills

Table 5, Textile Waste, 2019

2017 to 2022 is estimated at roughly 15%, making it the fastest-growing type of MMCF (Textile Exchange, 2019).

Another important fibre category gaining interest from consumers and industry professionals is represented by recycled MMCFs. Estimations show that, if only a quarter of the cellulosic textile waste would be recycled into MMCFs, the use of virgin wood would be completely eliminated (Fashion for Good, 2020). The latest reports suggest that conventional production methods will need to drastically change in order to protect vital resources, ecosystems and wildlife. A reduction in the industry's reliance on virgin resources could save more than 93 billion m3 of water currently needed for textile manufacturing annually (Ellen McArthur Foundation, 2020). Multiple academic studies have discussed the benefits of a circular fashion industry through the introduction of regenerated cellulose fibres from pre- and post-consumer textile waste into the sector's supply chain. Nowadays, an estimative 95% of the post-consumer cotton textiles are either sent to incineration facilities or landfills due to their depreciative state. In comparison, three quarters of the pre-consumer waste is recycled into reclaimed fibres and used for inferior yarns and nonwoven items (Liu et al., 2019). Chemically recycling cotton and other cellulose-rich post-consumer garments through technologies such as cellulose carbamate has been demonstrated to use less water compared to the viscose-obtaining process, as the preparation of the wood pulp requires water resources (Paunonen et al., 2019). An important innovator on the market of recycled cellulose fibres is Re:newcell, a Swedish company producing Circulose® pulp from dissolved cotton and other cellulose fibre waste (Circulose, 2020). During a primary interview, the company representant highlighted that their manufacturing process only requires a fragment of the water normally used for cotton production. Even the small amount necessary is completely treated afterwards in order to safely return back to nature. Their product managed to close the loop by offering a recycled alternative that can be easily introduced in the current



supply chain without any changes in consumers' preferences. Large-scale commercialisation of this closed-loop system can hugely impact the global usage of freshwater resources (See Appendix 2, xiv, pg. 46). The interview reinforced that companies such as Re:Newcell, regard water conservation and treatment as important aspects in the production process. In an industry first, a 5-year collaboration with the H&M group, Re:Newcell will supply enough raw material for manufacturing millions of fashion items (H&M, 2020), scaling up production and moving closer towards a cradle-to-cradle industry. However, during a primary focus group, concerns related to recycling being resource- and energy-intensive emerged, with the participant mentioning that consumers should simply start being more responsible with their purchases and reject fast-fashion (See appendix 3).

Even if this innovative technology will impact the future development of the fashion supply chain, the long-term company goals regarding production capacity expansion to 360 thousand tonnes by 2030, are not going to be enough to fulfil the growing demand for natural fibres, set to reach 260 million tonnes during the same period. Thus, the entry of other similar companies on the market is crucial for reaching circularity goals (Ellen McArthur Foundation, 2020, 11:50). Currently, a growing number of businesses such as Worn Again UK

and Infinited Fiber joined this particular market, already securing partnerships with big industry names such as Kering, H&M group (Worn Again, 2020) and Patagonia (Infinited Fiber, 2020). Globally, wider garment-to-garment recycling goals can also be hindered by the blended fabrics market, set to surpass 18 million tons by 2024 (Ahuja & Rawat, 2017). Due to unprofitability, blended textiles are not currently being recycled (Suntiger, 2019). Nonetheless, through a collaboration with the non-profit H&M foundation, the Hong Kong Research Institute of Textiles discovered a hydrothermal recycling treatment for cotton-polyester blends, capable to break down the fabric into the component materials (Barrie, 2017). This closed-loop process is cost-effective and environmentally-friendly, as it recycles water and only uses biodegradable green chemicals to transform post-consumer apparel of mixed fabric into their raw state. (H&M foundation, 2020). Today, cotton is still the most widespread fibre of botanic origin and the second most used raw material for textile manufacturing worldwide with a total market share of 23% globally. However, one can clearly note that the water-efficient small category of recycled MMCFs, currently estimated at less than one percent of all MMCFs, is going to increase in popularity with more and more companies turning pre- and post-consumer cellulosic textile waste into new fibres (Textile Exchange, 2019).

chapter III

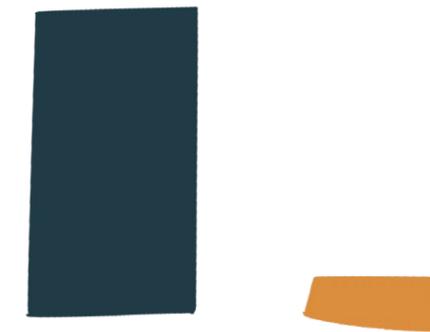
The role of brands and consumers

As freshwater is increasingly considered a precious resource, water-efficient textiles and technologies are gaining popularity among both brands and consumers. The following paragraphs will uncover the relationship between younger generations and water conservation efforts, as well as the ways in which certain brands are bringing a water revolution in the fashion industry.

The role of environmentally-savvy consumers in driving change has been previously discussed and acknowledged. In 2017, a Boston Consulting Group and Global Fashion Agenda study revealed that upper management employees working in sustainability departments regard the consumer as the most important variable in building a more sustainable industry (Eder-Hansen et al., 2017). Nowadays, the involvement of younger generations like Gen Z in social and environmental issues, undoubtedly impacts their buying decisions. Surveys with Gen Z consumers highlight their willingness to pay a higher price for sustainability, with 73% of respondents saying they would purchase sustainable products for up to 10% more. This type of behaviour not only impacts the retail industry, but all decisions of this generation (Furbee, 2020). The Mintel's Ethical Retailing report from August 2020 (UK) revealed that almost three quarters of those interviewed prefer to shop with a brand that supports a cause they believe in (Mintel, 2020). Primary interviews with Gen Z consumers passionate about environmental issues have uncovered the growing fear of global water scarcity becoming their daily reality. If fast-fashion retailers and other apparel companies will not change their production methods or stop supporting unsustainable industry practices, consumers will have to face this unavoidable crisis. One of the interviewees mentioned that even if many companies have dedicated entire departments to ensure the implementation of sustainable practices, not enough efforts are being directed towards meeting these goals. Therefore, the devastating effects of pollution are still deeply impacting environmental and human health (See Appendix 2, xx, pg. 47).

A study by Attari (2014) shows that the majority of consumers are unaware of their total water consumption, and mainly focus their conservation efforts on direct consumption activities. According to the paper, results indicated that respondents underestimated water use for a number of 17 situations. Additionally, most participants selected curtailment activities instead of efficiency-focused methods to save water in their household, with the minimisation of shower duration and turning off the tap being the most popular answers. Similar to the findings of the previously mentioned study by Attari (2014), primary evidence highlighted that respondents are more likely to restrict their direct water consumption, instead of the indirect volume they use, even if initial results showed that 86% regarded water-conservation as an important factor influencing their daily lifestyle (See Appendix 1, vi, pg. 45). This particularly oversimplified attitude towards preserving freshwater resources is causing consumers to overlook the amount of water utilised during various stages of the production chain (Gómez-Llanos, Durán-Barroso & Robina-Ramírez, 2020). Although the importance of climate education in the fight against pollution and climate change has been previously discussed (Anderson, 2013), a survey of 26,689 Spanish households revealed that a higher level of education and environmental awareness does not always correlate with conservation behaviours. In fact, even if well-educated individuals tend to support water conservation efforts, their modern lifestyle increases the level of water consumption (Mondéjar-Jiménez, Cordente-Rodríguez, Meseguer-Santamaría & Gázquez-Abad, 2011).

Consumer awareness regarding overconsumption and its negative environmental effects led to the surge in popularity of a lifestyle entitled "zero-waste". Based on empirical observation, this increasingly important trend is impacting consumer buying habits and how they use freshwater resources. Embracing "zero-waste" practices equals with striving to produce as little waste as possible and conserving valuable resources. Factual research shows that most



86% of consumers try to reduce their daily water consumption

Table 6, Water Consumption Mindfulness, 2020

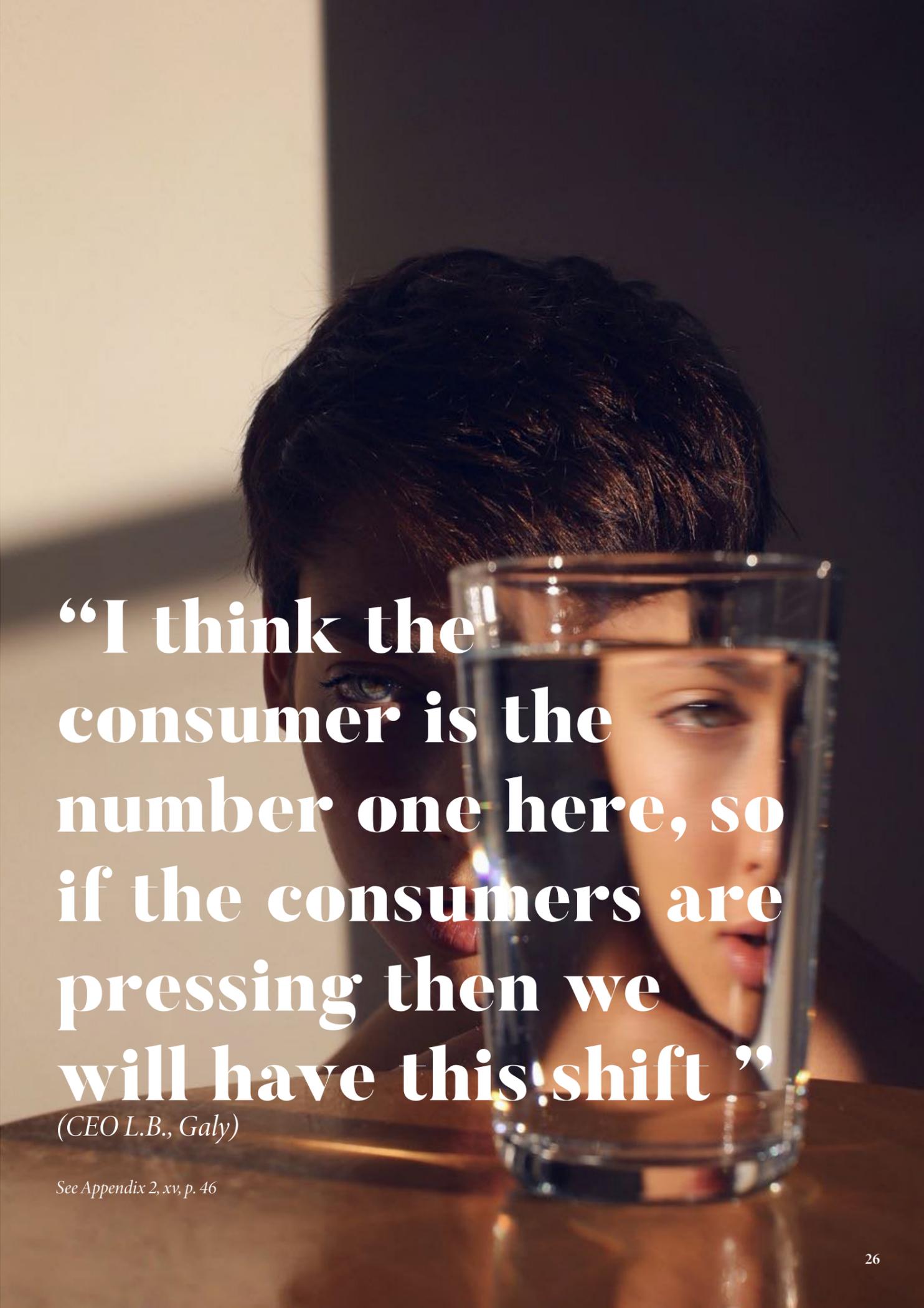


84% would choose to support a brand that recycles or uses less water

Table 7, Consumer Preferences, 2020

“zero-waste” bloggers and advocates recommend the installation of water-saving devices, shorter showers over long baths and recycling or upcycling garments. Primary interviews with consumers living a zero-waste lifestyle revealed that a crucial aspect of this particular trend is the efficient use of water resources. Zero-waste advocates reject conspicuous consumption and consumerism due to the resource-intensive production and the amount of landfill waste. One of the respondents mentioned her efforts to conserve water resources by rejecting fast-fashion, choosing upcycled or second-hand items and trying to reduce her overall indirect consumption (See Appendix 2, xix, pg. 48). This type of behaviour can be classified as “impact-orientated” rather than “intent-orientated”. The key difference between these two classifications is that “intent-orientated” actions emerge when a consumer has the intention to perform an eco-friendly activity without considering its efficacy or impact. In contrast, “impact-orientated” behaviour takes into account the effect of an action at a large scale (Stern, 2000).

Conventional textile manufacturing methods are rapidly growing out of fashion due to their devastating environmental effects. Untreated wastewater pollutes surface and subsurface water, while the ever-increasing solid waste breaks down in landfills, leaching dangerous chemicals into the soil and polluting groundwater resources (Uddin, 2018). As a result, increased environmental awareness among consumers is pushing brands to implement more sustainable manufacturing methods. In a primary digital survey, with more than half of the respondents between 18 and 25 years old, 80% indicated their interest in sustainable fashion (See Appendix 1, v, pg. 45), while 92% said fashion brands should reduce their WF, from fabric to manufacturing and even logistics (See Appendix 1, viii, pg. 45). The questionnaire also revealed that 84% would choose to support a brand committed to using less or recycled water in their production process, highlighting the increasing demand for sustainable industry practices (See Appendix 1, ix, pg. 45). Businesses play a crucial role in influencing demand on the supply chain and



“I think the consumer is the number one here, so if the consumers are pressing then we will have this shift ”

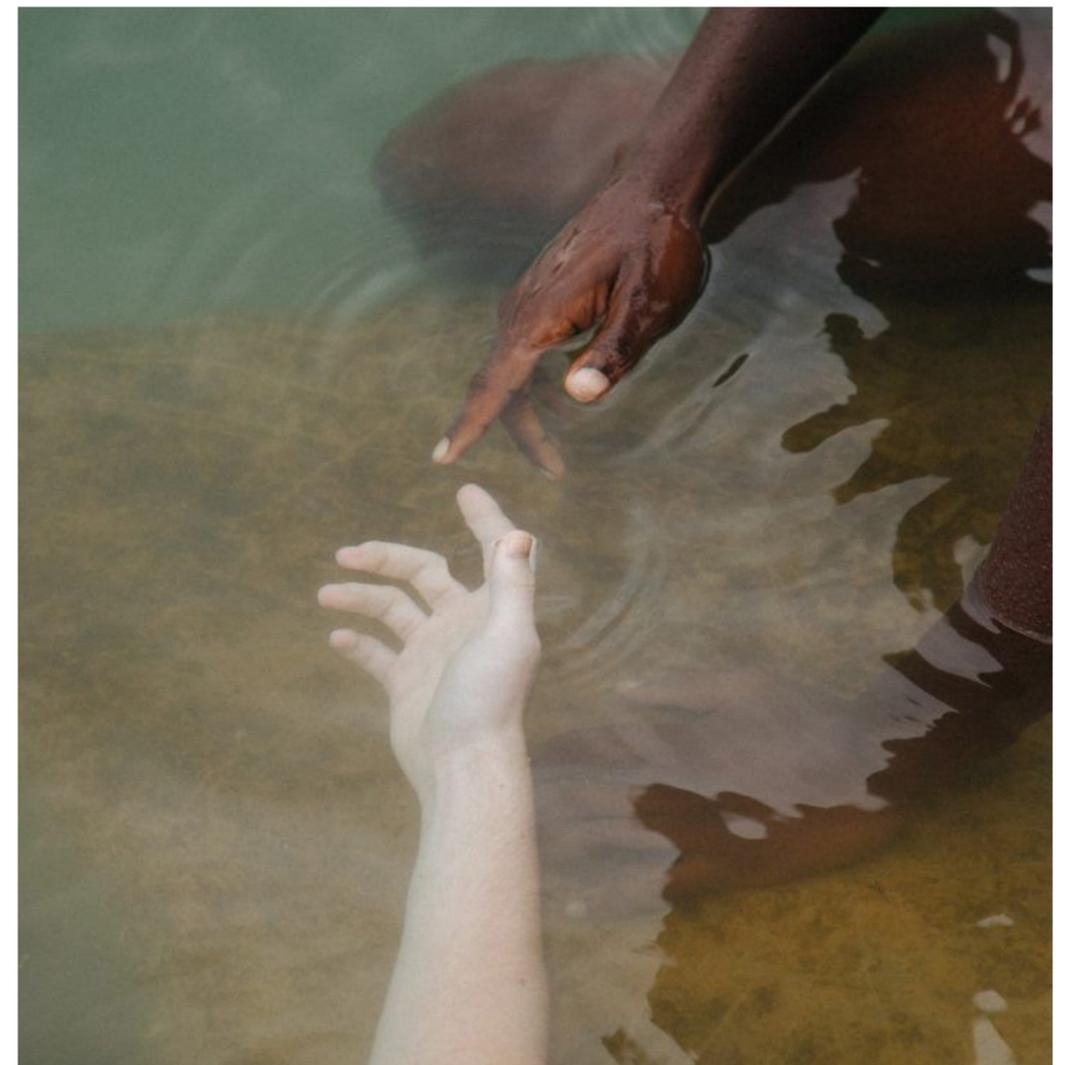
(CEO L.B., Galy)

See Appendix 2, xv, p. 46

production. If big industry players choose their manufacturers based on a specific material or production process, the probability that current practices will change increases exponentially (See Appendix 2, xiv, pg. 46). Over the last few years, fashion companies have started to invest in the development and implementation of innovative water-saving technologies to manufacture less resource-intensive products, while maintaining the same quality. Denim production is considered to be one of the most water-demanding processes in the fashion industry (Cernansky, 2020), prompting brands such as Levi Strauss & Co to make their production more eco-friendly. In 2014, the world-renowned jeans producer introduced a water-recycling microfiltration system to capture chemical particles from the process solution used in jeans manufacturing (Erdumlu et al., 2012). Moreover, in accordance with the World Health Organisation and United States Environmental Protection Agency guidance, the company became the first fashion brand to establish a new Water Quality Standard for producers in their supply chain. Their process called Water<Less™ uses up to 96% less water in the finishing stage of denim production and up until now, more than three billion L of water have been saved (Levi's, 2019). Other companies have joined the fight against water scarcity and adopted cutting-edge processes. For instance, apparel brand Wrangler have developed a sustainable foam-dyeing method to transfer indigo onto yarn, completely eliminating the use of water. Moreover, a growing

number of companies such as Patagonia and Armed Angels are also implementing more water-efficient production practices into their supply chain (Muthu, 2017).

At a macroeconomic level, freshwater can now be viewed as a world resource due to the international trade of water-intensive goods such as crops and natural fibres. The global nature of these supply chains is the reason why consumers have grown out of touch with the amount of water they indirectly consume. For instance, cotton clothes on the European Market are usually manufactured in Malaysia, using raw cotton imported from states such as India, China and Pakistan (Chapagain et al., 2006). The big discrepancy in the WF between people in different economic backgrounds is also worth highlighting. In the USA, the daily average is almost 8000 L of water per capita, while Chinese citizens only use an average of approximately 3000 L. The external WF of affluent countries is considerably bigger compared to that of developing economies. For instance, comparative data shows that 95% of the WF in the Netherlands can be traced back to other parts of the world, while in India's case only 3% is considered to be external (Water Footprint Network, 2020). To summarise, evidence presented in this chapter clearly shows that younger generations are driving a positive change and fashion companies are adapting to the increasing demand for water-saving fibres and manufacturing processes.

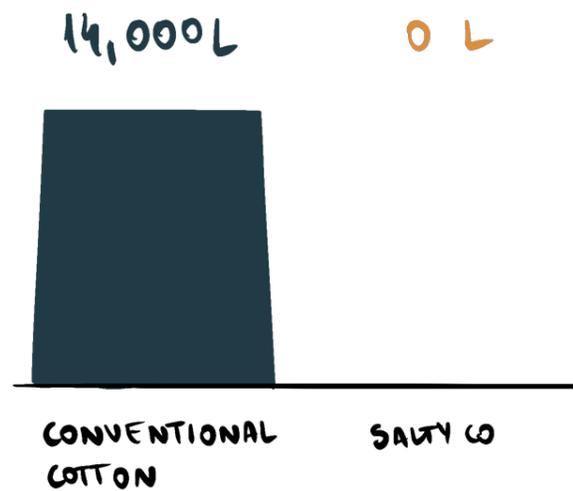


chapter IV

A freshwater-free industry

Innovative and water-efficient textile production methods under development have the potential to radically change the future of the apparel industry. Freshwater reduction achievements of emerging materials and processing technologies strongly support the argument of this dissertation. This chapter will discuss the potential impact of technologies such as lab-grown cotton and algae-based fabrics in the production phase, as well as the advancements being made in completely eliminating freshwater from the processing and manufacturing stages.

Conserving water resources and completely eliminating wastewater from processing mills is becoming a sustainability goal to make the fashion industry more environmentally-friendly. The implementation of innovative processes and materials that can considerably lower environmental pollution and support water resources conservation is becoming a crucial aspect in climate-change mitigation goals and transforming current textile manufacturing into environmentally-safe practice in the future (Hasanbeigi, 2013). Diminishing the amount of freshwater used in the raw material production phase has become an important objective for sustainability focused start-ups. One cutting-edge biotechnological system designed by Galy is lab-grown cotton. The company is able to grow real cotton from stem cells instead of plants, using only laboratory space instead of land resources. This innovation is up to ten times more rapid than conventional cotton cultivation, only needing 18 days instead of 180. Moreover, this technology requires zero pesticides and reduces both water use, and greenhouse gases emissions by 80% (Kart, 2020). A primary interview with a Galy representant revealed that the company produces their cotton in bioreactors using media component water, which can subsequently be recycled as the system is a closed-loop environment. Lab-grown cotton can be regarded as a better product in terms of quality and sustainability, while also offering a new perspective on agriculture and the textile industry (See Appendix 2, xv, pg. 46). Lab-grown technology can potentially replace conventional agriculture with a process that offers higher resource efficiency and a safer working environment.



Compared to conventional cotton, Salty Co fabrics do not use any freshwater resources

Table 8, Cotton and Salty Co fabrics comparison, 2020



“ now we're
 looking to what
 tomorrow's sustainable
 standard will be
 - freshwater-free
 fabrics ”

Engineer Julian Ellis-Brown for Dezeen

(Aouf, 2020)

The need for water-free and sustainable textiles has fueled worldwide efforts of finding renewable fibre resources which can be transformed into qualitative goods. Another recent innovation with applications in the textile sector is algae-based fibre. Seaweed is an untapped resource that is considered to hold great potential in terms of sustainable raw materials. It does not utilize soil, irrigation, freshwater or any dangerous pesticides and fertilizers (Ahmed, 2020). As early as 2010, a research team from the Qingdao university in China succeeded in the extraction of strong kelp fibres for textile applications. Based on the country's available algae resources, the potential fibre output could reach 1.9 million tons yearly, substantially decreasing the country's reliance on water- and pesticide-intensive cotton (Pauli, 2010). One promising company investing in algae-based textiles is Algalife. A Berlin-based start-up that aims to design fibres, as well as dyes from microalgae (Algalife, 2020). As mentioned in an interview by their CEO, Renana Krebs: "The manufacturing process of growing the algae takes place in a closed loop, is powered by solar energy, has no negative impact on nature or on workers, and doesn't even require freshwater as saltwater is used" (WSA, 2020, p. 12). Their innovative fabric also intends to offer a few of algae's natural antibacterial and anti-inflammatory properties, as well the release of vitamins, proteins, antioxidants (WSA, 2020). Empirical evidence shows that the number of companies interested in eliminating freshwater from the manufacturing process is increasing. The fashion industry is starting to look towards the ocean to find sustainable raw material alternatives for natural fibres. A team of students from the Royal College of Arts have developed a textile made from salt-tolerant plants that grow in salt marshes. These are ecosystems considered to be essential habitats for a healthy and diverse environment (SaltyCo, 2020). Their discovery can potentially shift the current freshwater-hungry production methods to freshwater-free manufacturing of various apparel products such as t-shirts, trousers, faux leather and insulation in the future (Aouf, 2020). The prospect of using algae for replacing



cellulose-rich raw materials like cotton and wood pulp is becoming a viable and sustainable alternative. In an ABC podcast “Algae - a new sustainable resource” the speakers discuss how harnessing the power of algae can potentially shift the current system by creating the same fundamental fibres without the wastage and pollution. The process of cultivating microalgae is very sparing on resources, especially water, as it only requires sun, CO₂ and depending on the species, even industrial wastewater. Moreover, the growth rate is ten times faster than bamboo trees as the mass of the plant can potentially double each day (ABC, 2018). Using a HRAP system is a cost-effective option of industrial water treatment and algae biomass production. It encompasses a photobioreactor and oxidation ponds which help microalgae to supply oxygen for bacteria, while allowing bacteria to transform chemical compounds into nutrients (Molazadeh et al., 2019). Even if such technological advancements are considered to be essential for a sustainable development of the apparel industry, it can also be argued that large-scale adoption of these emerging technologies could leave millions of farmers and garment workers in developing countries without employment (Monbiot, 2020). However, different species of algae and saltwater plants are increasingly regarded as valuable raw material resources with a great potential to replace cellulose-rich fibres such as cotton or lyocell.

As discussed in previous chapters, freshwater resources are not only used for raw material production, but also for key processing stages, making finished textiles the result of a very resource-intensive process. Hence, many sustainable and innovative textile processing methods are currently under active development or already in use commercially at a small scale. The majority of contemporary water-efficient technologies available have not managed to completely eliminate water, even if the little amount used can be completely recycled. However, industry professionals and visionaries like Jeanologia believe in a water-free industry and a lot of efforts are being made to develop waterless textile processing technologies (Jeanologia, 2020). This Spanish start-up has managed to design and implement multiple water-saving and waterless jeans processing technologies, which allowed savings of up to 13 million m³ of water in 2019 (Warren, 2020). Currently, almost 35% of all jeans

worldwide are finished using Jeanologia technology, but the company aims to make the entire jeans processing industry water-free by 2025 (Veasquez, 2018). With technologies like nano-bubble (E-flow), “ozone washing” and laser treatment, Jeanologia have been able to achieve great water and chemical reductions, while also eliminating the use of environmentally-damaging practices such as the use of potassium permanganate, pumice stone, manual scraping and traditional washing (Innovation Textiles, 2020). The E-flow technology can reduce water use up to 98% and eliminate wastewater from the jeans manufacturing process (Khalil, 2016). Moreover, “ozone washing” can potentially bring a real revolution in the washing industry, as it can also be used for casual wear and not only denim (Garcia, 2015). The company has also managed to develop an ozone treatment for continuous fabric, called G2 Dynamic. This zero-discharge process can save water resources up to 95%, reduce costs and also increase productivity. If conventionally 1 kilogram of fabric uses approximately 20 litres of water, with the G2 Dynamic, the complete process only requires between 0.5 and 3 L/kg (Innovation Textiles, 2019). Another important water-saving technology is the laser treatment, as it can replicate most special wash effects such as bleach, stone and mill wash (Saha, 2018). However, even if decreasing the number of steps in the finishing process using newly available technology will significantly reduce the amount of resources used, it also facilitates the acceleration of the fashion cycle. This can subsequently lead to environmental degradation and higher global warming rates due to an increased number of garments reaching landfills (Herranz, 2018). Furthermore, the growing need for clean waterways has prompted the development of cutting-edge textile dyeing technologies. ColorZen is a company bringing innovative technology on the market with a cotton pre-treatment which makes the fabric more responsive to dye, resulting in 90% water savings and zero toxic discharge (Hepburn, 2015). Eliminating dangerous synthetic substances from the dyeing process influenced multiple academic studies and companies’ research focused on developing natural dye alternatives from algae-based pigments. A partly EU funded study “LIFE SEACOLORS” from Spain, proved the potential and viability of using natural, eco-friendly and non-toxic algae dyes for textile finishing to considerably reduce the amount of grey water resulted after conventional dyeing and printing methods, as well the blue water needed for plant pigments production (Life Seacolors, 2016).

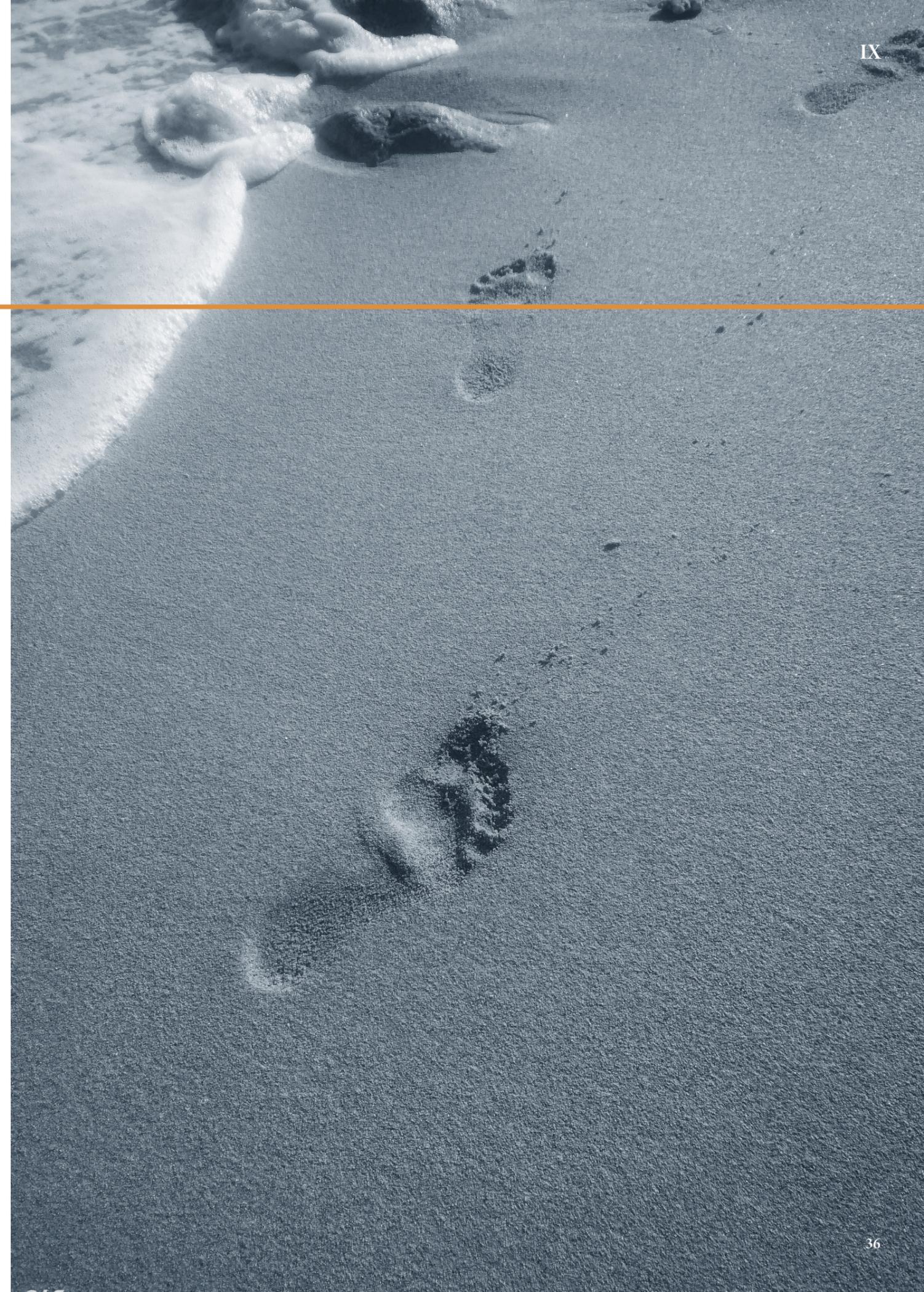
conclusion

Even if cotton is currently the most widespread natural fabric worldwide, increasing global water scarcity concerns are prompting research into the development of new sustainable ways to produce water-efficient, natural and sustainable fabrics. The freshwater availability crisis is being exacerbated by the fashion industry's high volumes of water consumption throughout the entire supply chain. Secondary research revealed that due to its popularity and production methods, cotton is considered one of the main causes behind unsustainable irrigation, amplifying water scarcity in already stressed regions around the world (Mekonnen & Hoekstra, 2020). Moreover, textile dyeing and treatment are also considered the number one cause for water pollution in developing countries where these activities take place (Regan, 2020). The depletion of water resources either by unsustainable extraction or contamination is causing extensive damage to both ecosystems and human health. As water is an essential element in fashion production and manufacturing, increased water scarcity will not only impact social and environmental aspects, but can also have devastating economic consequences at a global level. Both primary and secondary research carried out in the support of this subject, demonstrated the growing demand for the fashion sector to rethink current practices and substantially decrease its reliance on water through the adoption of more resource-efficient manufacturing methods. Counter arguments such as the practicability of cotton fibres or the creation of employment in developing countries have also been discussed. One could also say that the cotton farming and textile dyeing industries create jobs for workers that depend on the income to support their families. However, the extensive environmental damage and negative impact on human health caused by these practices far exceed the advantages on the long term.

Current alternatives considered water-efficient such as organic cotton, do not represent a viable solution for the sustainable development of the industry, due to relatively low water savings and possible post-processing chemical discharge still posing a threat to

aquatic systems. Furthermore, even if man-made cellulosic fibres (MMCFs) such as Tencel Lyocell do not require irrigation to grow the raw material (wood pulp), changing green water distribution can negatively impact blue water flowing down-stream. Nonetheless, latest technology into recycled MMCFs is offering a promising perspective on the future of this particular category, expected to see a surge over the future (Textile Exchange, 2019). Moreover, reflecting on the dynamic between consumers and water scarcity in relation to the fashion industry, it is becoming evident that water conservation efforts are already impacting buying decisions. Primary research revealed that younger generations are more prone to choosing apparel that complies to their values and support fashion labels that strive to reduce their WF. The surge in popularity of the zero-waste lifestyle and sustainable living has resulted in a large number of consumers focusing on reducing their overall consumption, including the indirect water use. However, it is crucial to highlight that the large majority of consumers do not consider the indirect consumption when asked about their water conservation efforts. Following on, the number of fashion labels committed to reducing their WF is also growing, with reputable names such as Levi's investing in the development of water-efficient processing technologies.

As the world population is growing at a fast pace (Boretti & Rosa, 2019), finding freshwater-free sources for raw materials and waterless manufacturing methods is becoming a great concern to industry professionals. Promising new technologies such as lab-grown cotton, fabric made from salt plants and algae-based natural fabric can offer a sustainable and even freshwater-free alternative to conventional cotton. This dissertation provides clear evidence that the future development of natural textiles will be impacted by increasing global water scarcity. Better water management systems and completely eliminating freshwater from the fabric production and manufacturing stages will become a key aspect in the sustainable development of the fashion industry.



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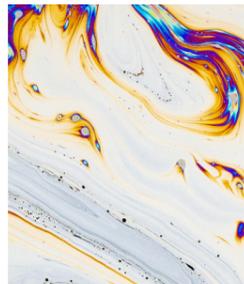
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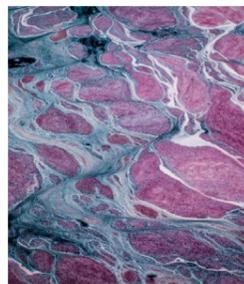
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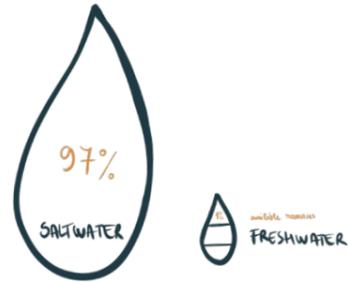
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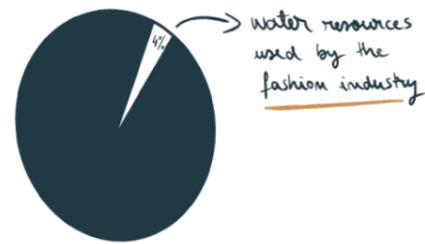
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Table 1, Total water available globally, 2014



Sharghi K. (2014, Aug 14). The Three Percent. Nasa. Retrieved from: <https://svs.gsfc.nasa.gov/11595>

Table 2, Fashion industry water consumption globally, 2017



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Table 3, Industrial water pollution, 2019



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Table 4, Tencel Water Consumption, 2020



Ellen McArthur Foundation. (2020, Nov 5). What Will Our Clothes Be Made Of in a Circular Economy? | The Fashion Show Episode 4 [Video file].

Table 5, Textile Waste, 2019



Liu, W., Liu, S., Liu, T., Liu, T., Zhang, J., & Liu, H. (2019). Eco-friendly post-consumer cotton waste recycling for regenerated cellulose fibers. Carbohydrate Polymers, 206, 141-148. doi: 10.1016/j.carbpol.2018.10.046

Table 6, Water Consumption Mindfulness, 2020



Primary Research Survey: Is freshwater scarcity going to influence the development of sustainable natural textiles? (2020) (See appendix 1, vi, p. 45)

Table 7, Consumer Preferences, 2020



Primary Research Survey: Is freshwater scarcity going to influence the development of sustainable natural textiles? (2020) (See appendix 1, ix, p. 45)

Table 8, Cotton and Salty Co fabrics comparison, 2020



Gardetti M. & Muthu S. (2019). Organic Cotton. Springer Singapore, Imprint: Springer.

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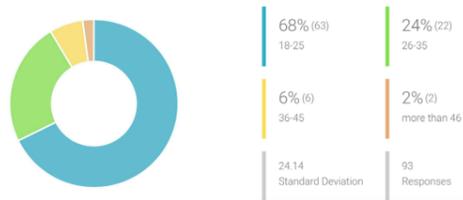
Appendices

Appendix 1: Digital Survey

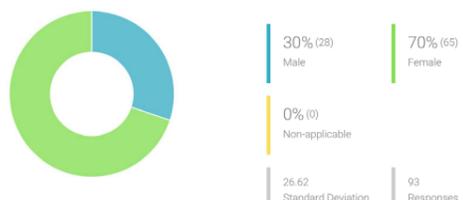
Primary Research Survey: Freshwater Scarcity and Consumers

- How old are you?
- What gender do you identify with?
- What geographical are do you live in?
- Are you interested in sustainable fashion?
- Are you familiar with the issue of global water scarcity?
- Do you usually try to be mindful of your daily water consumption?
- If you had to estimate how much water you use on a daily basis, what would you answer?
- Do you believe fashion brands should aim to reduce the amount of water they use in their supply chains? (from type of fabric to production processes

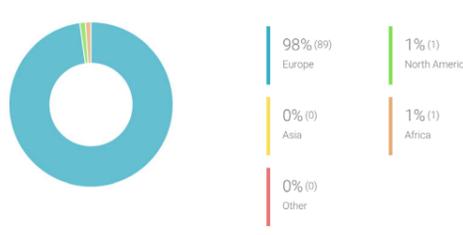
(i) How old are you?



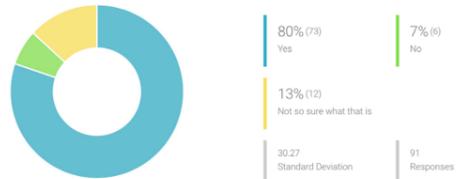
(ii) What gender do you identify with?



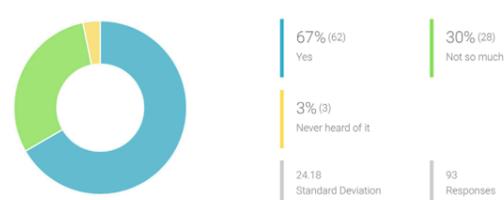
(iii) What geographical are do you live in?



(iv) Are you interested in sustainable fashion?



(v) Are you familiar with the issue of global water scarcity?



- and logistics)
- Would you be more inclined to purchase an item from a brand that uses less or recycled water in their production process?
 - Do you think it is important for a fashion brand to get involved in social actions like helping and protecting communities affected by water scarcity?
 - Would you choose to support a fashion brand that donates towards the above mentioned causes over one that does not?
 - Is there any fashion brand that comes to your mind for performing social actions or raising awareness about the issue of freshwater scarcity?
 - Please order the following environmental issues based on your personal considerations in terms of which one you believe to be the most urgent or likely to affect our future at a global level nowadays:

(vi) Do you usually try to be mindful of your daily water consumption?



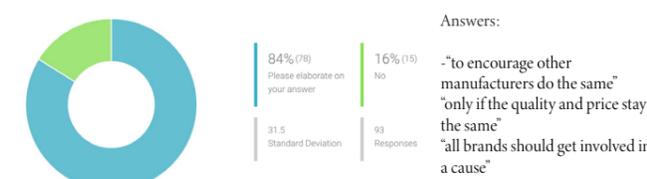
(vii) If you had to estimate how much water you use on a daily basis, what would you answer?



(viii) Do you believe fashion brands should aim to reduce the amount of water they use in their supply chains? ...



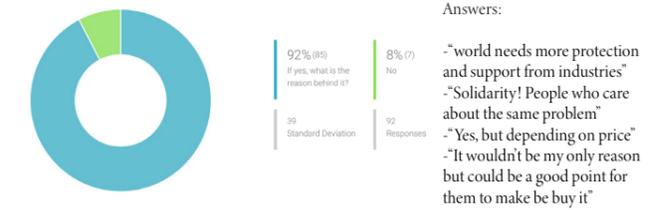
(ix) Would you be more inclined to purchase an item from a brand that uses less or recycled water in their production process?



(x) Do you think it is important for a fashion brand to get involved in social actions like helping and protecting communities affected by water scarcity?



(xi) Would you choose to support a fashion brand that donates towards the above mentioned causes over one that does not?



(xiii) Please order the following environmental issues based on your personal considerations...



Appendix 2: Qualitative Interviews

Primary Interview: RE:Newcell Brand Manager N. E. (Circulose) (xiv)

- Please tell me more about the way you use water resources throughout the process of obtaining Circulose.**
Producing Circulose requires a fraction of the amount of water used to produce traditional cotton. The water we do use is treated and cleaned to the extent it can be released back into the lake next to our factory, Vänern.
- What is your opinion on current manufacturing practices used in the fashion industry to produce garments from a water-usage point of view? Do you believe there is still time to completely change these unsustainable processes? (conventional cotton growth, organic cotton etc).**
That would of course depend on how you define "still time" - I believe we have no choice but to change the unsustainable processes in place today and move towards circularity if we want the earth to survive. In many ways we are working way to slowly and hopefully this will accelerate now with a higher demand for sustainability. What is important to make this change effective and as fast as possible is to produce in a much more circular and sustainable way - but keep the high quality and preferably drop-in products. Meaning the customers do not have to change their preferences, manufacturers do not have to change all their machinery and so on. This is also the core of Renewcell, producing a recycled product that can be used in the existing supply chain without extracting new resources from the planet.
- Do you believe fashion and in particular, water-efficient textiles have an important role to play in reducing the issue of global freshwater scarcity?**
Definitely, we are using excessive amount of water to produce clothes where 85% of the clothes end up in landfill after being used for a short period of time, if at all. If we could develop ways of producing clothes using less water, preferably in a closed loop system, combined with recycling the clothes we do produce it will make a huge difference on the global freshwater usage.
- Do you believe that recycling cellulose-rich clothing into new garments has the potential to completely replace the need for growing virgin cotton?**
At Renewcell we can see that demand for recycled materials are only growing and the feedback on the clothes made from our material is really positive. I believe this question is a matter of financial investment to be able to scale the production of recycled material. Important to note is that these materials must have the same feel and quality if we would like to directly substitute traditional materials without customers preferences changing, which would require much more time and efforts. Once this is at the scale we need I don't see a reason to not use it.
- From your own experience, is it true that there is an increasing number of consumers interested in sustainable fashion and if yes, do you believe saving water is an important aspect to them?**
We can definitely see an increase in demand for more sustainable materials and productions, not saying it is at the level it should be. The demand is probably increasing for a variety of reasons, water usage being one of them. The statistics of how much water the production of a pair of denim jeans requires is a highly debated subject and something I know many consumers have reacted to. Then again, it can be difficult for consumers to really grasp the environmental effect that fashion actually has, but there is absolutely an increasing demand.
- Do you believe sustainable fashion brands will have an impact on changing the current model of water consumption in the industry?**
What we've seen is that it's the consumers who demand sustainable practices which forces the brands to deliver. There are also many brands that would like to do better as they realize and understand the effect their production and sales has on the environment. Considering this, the brands are playing a key role in demand on supply chain and production. If a large brand demands their producers to produce using a certain material or sustainable practice, the probability is much higher this will change.

(xii) Is there any fashion brand that comes to your mind for performing social actions or raising awareness about the issue of freshwater scarcity?

Stella McCartney	Stella McCartney
I saw a Levis campaign a few years ago	Wrangler
no	Levis
no	Attire
400	H&M
	Puma
	Adidas
	Eileen Fisher

Primary Interview Galy CEO L. B. (Lab-grown cotton) (xv)

- Please tell me more about the way you use water resources throughout the process of obtaining GALY cotton.**
So basically we are producing the cotton on bioreactors so the water used there is mostly media component, basically water and sugar, but at the end of the day this water is recyclable because it is a closed-loop environment so yeah the water resources here are minimal.
- What is your opinion on current manufacturing practices used in the fashion industry to produce garments from a water-usage point of view? Do you believe in the future the industry will be able to completely change these unsustainable processes? (conventional cotton growth, organic cotton etc)**
I think people are still on the learning process. I think consumers are pressing the brands to make sure they are working with more sustainable practices so not only in the water-usage but also Co2 and many other issues related to the pollution or not the best use for resources in the textile industry. So, I believe that the industry will be able to completely change, but it is just a matter of time and effort. It takes time to shift an entire industry to a new place, but I think we are going into a very good direction here.
- Do you believe fashion and in particular, water-efficient textiles have an important role to play in reducing the issue of global freshwater scarcity?**
Definitely, yeah. So if you look at cotton production in Uzbekistan, was one of the main causes there for getting all the water from a specific sea. So definitely I believe it has an important role, but sometimes people are not aware about the amount of water used for cotton production for example. So I think we still need to work towards getting more people informed.
- Do you believe that your innovation has the potential to completely replace the need for growing virgin cotton in the future?**
I don't think this is the best way to describe our innovation. I believe the best way would be to revolutionize how we are producing cotton today. So we wanted to make it possible for people to create a cotton that everybody loves, probably a better product in terms of quality and sustainable practices, but also give people the opportunity to think the agriculture and textile industry in a different way. So with the actual consumption and the amount of people that we have on the planet, increasing numbers by 2030 2040 we need to do something. So I would not say replace but revolutionise, in order to have a better path for the world in general.
- From your own experience, do you believe that the increasing number of consumers demanding more sustainable practices (including freshwater-efficient textiles) will have an impact on how the fashion industry currently uses water resources?**
Yeah, definitely. I think the consumer is the number one here, so if the consumers are pressing then we will have this shift and you can see very cool brands being born with this like Allbirds or Pangaia or many others that are looking to be sustainable first and fashion second.
- How do you believe cotton farmers in developing countries will be affected by new technologies like yours?**
I think our main idea here is not to displace them. It's funny that whenever people are talking about cotton farmers they think they are very happy and having a nice house, but that is not how it works. You have 2 main groups, the one which is the big farms who have a lot of automation and money and don't care about sustainability, and the second group is represented by the farmers who are really really poor, lack the infrastructure and knowledge, they depend on the seeds and the chemicals. So whenever the companies that sell the seeds are forcing them to buy more because they can't get the same yield every year, they are losing money, and at the end of the day you see the death rates of those places from the farmers killing themselves just because they are full of debt or because the use of specific chemicals so I would say that it is not going to affect them, but probably give them a bigger or different opportunity to help on this cotton journey.

Primary Research Interviews with Gen Z consumers:

1. *Are you familiar with the issue of freshwater scarcity? Do you hear about it a lot or do you search for information related to this yourself?*
2. *Have you heard about the water footprint concept?*
3. *Do you know how much water we consume on a daily basis?*
4. *Do you ever try to reduce your water consumption? If yes, what do you do about it?*
5. *Do you ever think about your indirect water consumption? (Virtual water consumption: all products you buy have embedded water in them due to the necessary resources that went in their production)*
6. *Do you find the prospect of freshwater scarcity to be daunting?*
7. *What are the most sustainable alternatives in terms of water-use nowadays?*
8. *Do you believe your fashion choices can impact global water scarcity?*
9. *Do you know any fashion brand that is involved in raising awareness or bringing social change thorough projects related to tackling freshwater scarcity?*
10. *How do you think the fashion industry should get involved in tackling the issue of water scarcity?*

Answers:**Participant 2, female, 20 y/o, Sheffield (xvii)**

1. I am familiar with it, I don't hear that much about it mainly on the news regarding droughts in Africa.
2. No I haven't but I think it would be interesting to know how much water I use/consume
3. No I don't
4. I do, I try to not stand in the shower for too long as I feel like it is such a waste especially when there are people in countries that can't even get the adequate amount.
5. No I don't but I think it will be interesting to know what the products I buy are made up from. I only know more about water consumption when it comes to denim and cotton materials.
6. Not particularly, I think I live in a privileged world where we don't have to think about things too much where as in third world countries its just the norm to not have fresh running water. I think we need to be educated more and taught how we can reduce our water consumption or have a limit of using it.
7. Im not sure on this, I don't know if this is related but I know lush do a toothpaste pill sort of thing where you can use it on the go, I guess that doesn't need water?
8. I don't think my choices will I think It needs to be a collective, fast fashion is taking over the fashion industry making it very difficult for independent brands who are sustainable to educate their target market.
9. No
10. I think brands need to be more transparent with their products such as mentioning how many litres of water it took to make this shirt.

I feel like labels like that could make consumers think more about their buying decisions.

Participant 5, female, 22 y/o, Berlin (xx)

1. Yes! I have recently become more aware about my consumption as an individual and the amount of waste me and my household generate. Water scarcity has become a very important topic within the climate change discussion.
2. Yes I am familiar with this concept but I do not know my personal water footprint.
3. I'm not completely sure, but I do try to use as little as possible on a daily basis. I would say around 400 L per day.
4. Yes. Since I started to live a more waste-free lifestyle I also reduced my water consumption. This means that I decided to adopt methods like shorter showers, turning off the tap when not using it, collecting rain water for my garden, but also eat less meat, buy less clothes and reuse most of the products I buy.
5. I know how much water cotton uses and try to buy second hand instead of new clothes all the time. Also I always try to search for the most sustainable alternative when I need to purchase something new for myself or the home. I choose recycled or upcycled if there is this option.
6. It is very scary indeed. Makes me very sad sometimes that people simply do not care or realise how grave these issues are.
7. I think that we need a standard for water quality that all fashion brands should respect. It is not enough that sustainability is only a choice and not something compulsory. Fast-fashion retailers do not need to change because there are no regulations they need to follow and their recklessness is impacting everyone. Even if many companies (from fashion to other sectors as well) now have sustainability dedicated teams and departments, it is not enough to stop the process of climate change or protect humans and ecosystems from the negative effects of pollution.
8. Yes, I believe that fashion consumes huge amounts of water and as consumers we have the option to choose right. Recycled instead of virgin resources.
9. I know Wrangler are doing some research into how to produce jeans using less water.
10. In my opinion brands should educate more and lead the sustainable movement against climate change and implicitly water scarcity.

Participant 3, female, 23 y/o, Bucharest (xviii)

1. I first heard of it when watching a series on Netflix called "Explained". Other than that, I don't hear about it a lot on TV or on social media. Usually people share more content about fast-fashion and plastic pollution. I personally started to research into this subject a while ago and find it very scary. The amount of water we use on a daily basis is insane.
2. I never heard of it no, but I can assume by its name that it has something to do with how much water we consumer or a specific area consumes. I would like to learn more about it.
3. This is a very good question I believe everyone should know how to answer. I know we consumer less than Americans, so a few thousand L per day, if we take into consideration all the products we buy and use.
4. Yes. All the time. I stopped eating meat when I learned how many

resources have to go into the production, as well as the cruel methods used. Other than my diet, I also try to be mindful of the amount I use in the shower, laundry, and at the tap. I also try to reuse as much as possible instead of buying new all the time.

5. Yes, as I said before, I try to buy vintage, reuse, swap with friends. I also try not to wash my jeans and steam them instead while I shower. I think that being waste-free is one of the things you can do to conserve resources, especially water.
6. Yes, very much. I am 23 years old and I feel very scared about the future. It sometimes causes anxiety and stress that I cannot control. Climate change and the uncertainty of a prosperous future makes me think twice before even starting a family.
7. I believe the fashion industry can invest in the new technology available to move towards a sustainable future at a faster pace. Currently, growing cotton, manufacturing and production are harming the environment and deplete our resources. I believe that supporting innovative brands and companies is the only solution to make the industry sustainable.
8. Yes, absolutely. I believe every choice counts and if I choose to reuse a T-shirt by buying vintage instead of a new HM one, then I can save some 2,000 L of water.
9. I know that Armed Angels and Levi's have done some good campaigns.
10. I think brands need to be more transparent with their products such as mentioning how many litres of water it took to make this shirt. I feel like labels like that could make consumers think more about their buying decisions.

Participant 4, female, 24 y/o, Plymouth (xix)

1. Yes, very much so. I first heard of it in school during a German class when our teacher was showing all the different ways, we can save water on a daily basis. Since then, I started to be more interested in why do we have to save water and discovered that not everybody was so lucky as I was to have non-stop access to this precious resource.
2. I haven't no. But I wish I would have heard of it in school and hope that future generations will have the chance to.
3. I don't know exactly, but I can assume the amount is different from person to person. I do know that my choices influence the amount I consume and it is not only the water that comes out of the shower or tap that I use.
4. Yes. One of the main ways is collecting rainwater for my plants instead of using the tap. I also turn off the tap and shower when brushing my teeth or showering.
5. I am currently embracing the waste-free lifestyle and try to reuse as much as possible, even if it's very hard sometimes. I think that being mindful of the amount of products we consume is very important and this is why I also encourage my friends to reuse instead of buying new. I never buy from fast-fashion brands and choose vintage or upcycled garments instead.
6. I was very scared a few years ago, but I am better now as I see that more and more people are becoming aware of the issue and trying to do something about it.
7. I think the fashion industry should completely rethink their operations and supply chains because at the end of the day money cannot buy the health of our planet, and without a healthy planet we cannot survive. Small sustainable labels are starting to gain spotlight, but we still need that giant retailers like Primark, Zara and HM to be held

accountable for their actions against the environment.

8. Yes! I believe that buying from fast-fashion companies is offering them support to keep giving garment workers a inhumane treatment and dumping all those toxins in waterways, affecting ecosystems and human health.
9. I have read about a company called Blue Ben. I believe they use fabrics that are water-efficient.
10. I think brands should be more involved in educating the consumer about the environmental impact of their choices.

Participant 1, female, 21 y/o, Manchester (xvi)

1. Yes I'm familiar with the issue, however I don't hear a lot about it, I would only know about the issue from searching about it.
2. No I've not heard of this.
3. I'm not aware of the specific amount but I'm sure it is a lot.
4. Yes I try to, I don't leave the water running when not in use e.g. the tap or shower.
5. I don't actually think about this. Although recently I found out how 10,000 litres of water is needed to make a single pair of jeans which was an eyeopening fact about the fashion industry water consumption.
6. Yes
7. Things like ensuring that we turn taps off when not in use. Only using washing machines / dishwashers when it is a full load etc.
8. Yes because the fashion industry uses so much water that choosing a brand with high water consumption rates would impact global water scarcity.
9. I actually don't which is a worrying thing as this should be an issue which fashion brands try to make positive changes to.
10. They could maybe use recycled water? Having good water management? Aiming for less water pollution.

Participant 7, 25 Y/O, Bucharest (xxii)

1. I am a person who likes to actively be involved in climate action. I am vegan and also try to live a waste-free, eco-friendly lifestyle. Water scarcity has been an issue that caught my attention years ago and I started researching how can I reduce my water consumption.
2. Yes I have! I think it's a very good way to know how much water we actually need to make a certain product.
3. It really depends on the country you live and your lifestyle. The highest water consumption is in the US, but consumption rates in the US are higher than anywhere in the world anyway. I live in Romania and we have an average consumption compared to other European countries. I would estimate approximately 4,000 L per day, but I definitely consume less.
4. I try to reduce my direct water consumption by avoiding long showers, bottled water and only using collected rainwater to water my plants. I also avoid buying new items and only use clothes from vintage shops. I'm also reusing a lot of the stuff I buy and get a lot of tips from facebook groups.
5. Yes. I think anything you can do to reduce your waste and reuse as much as possible is good for saving water resources. My waste-free lifestyle has taught me that even if you are only one person, your consumption habits can have a huge impact on the environment. I believe we should all start to rethink the way society has evolved in latest years and change the way most people live their lives.
6. At some point in my life I was so scared about all these environmental issues that I was in a state of depression and anxiety. Since then I learned that being anxious about something you cannot control so I started to make steps towards changing my own lifestyle. Now I find it very satisfying to be in control of my life and my choices.
7. I believe they should definitely put more effort into changing the way this industry works. There are a lot of new technologies in the development phase and many brands could invest in adopting these.
8. I know cotton is currently being grown in dry regions of the globe so I believe if we as consumers reduce demand for these products change is going to follow.
9. Not directly in relation to water consumption no.
10. Yes of course. I believe fashion is responsible for many environmental issues and to my mind they should clean up their mess!

Participant 8, female, 24 y/o, Bucharest (xxiii)

1. Yes, I've been hearing about it for years now and I don't understand how people can be unaware of it.
2. Yes, a lot of scientists and academics have been using this framework to measure the impact on water resources for different processes or products.
3. I mean this is a very relative question depending on country and social hierarchy. If you're asking me personally, I know I am using a lot less than most people, but the average citizen consumes way more than needed. Approximately 1,000 a day or more probably.
4. I live a waste-free life. I am a vegan and do not consume any animal products, which apart from the obvious benefit of not killing innocent creatures, I am also saying No to a huge waste of water resources and green house gases emissions.
5. I reuse everything I buy and I buy everything recycled or made using natural materials. I try to absolutely avoid plastic and non-recyclable materials when shopping and I also have a special compost bin and use that for my garden instead of contributing to climate change by just throwing stuff away and waiting for someone to come get rid of it.
6. I think this is something that should be very scary for everyone, no matter how rich or poor. Freshwater is the one thing that cannot be substituted and is absolutely essential for human health.
7. I think fashion should be more sustainable and design in an eco-friendly way. If a product takes thousands of liters of water to make then just don't do it or find a better way.
8. Yes from what I've previously read. Fashion is a huge water consumer and they need to change their ways.
9. Only Levi's.
10. I think they should be more honest about their factories and production methods. Stop lying to consumers and sugarcoat everything.

Participant 6, 24 Y/O, Bucharest (xxi)

1. Not really. I don't hear much about it either. We had a lesson once in school about it but people don't talk about it much.
2. No.
3. Not really, I would estimate a few hundred litres. I know for a fact that one toilet flush used 9 L of water!
4. I try to sometimes. I cannot say that I am actively doing it though. I don't stay in the shower much and turn off the tap when doing my skincare or brushing my teeth.
5. This is an interesting question. I do like to buy second hand and upcycled garments, but I also like to get new items from the latest collections. I also don't like to waste food and avoid eating meat, but more because of health reasons.
6. I am sure if I start reading about it, yes.
7. I think that the fast-fashion model is something that needs to be banned because of the huge impact on the environment. The government should put regulations in place to make sure these kind of ecological disasters cannot happen.
8. I believe all our choices can impact the environment. We are more than 7 billion people living on this planet and we need to be more sustainable if we want our children to have a future.
9. No, I'm sorry.
10. I'm not sure, but I believe stop doing cheap and bad quality items would be a start.

Participant 9, female, 25 y/o, Bucharest (xxiv)

1. Yes, I am familiar with the issue of freshwater scarcity as I strongly believe that many people have treated water like an infinite commodity. Unfortunately, not so many people are aware of this problem and have no clue regarding how to manage water and that the amount we waste has long-term ramifications. I try to constantly search for information on this topic and how to prevent water waste.
2. Yes. Water footprint represents the amount of water directly and indirectly used to support human consumption activities.
3. Globally, the United States is the largest user of industrial water, withdrawing over 300 billion m³ per year. This is significantly greater than China, the second largest, at 140 billion m³. Most countries across the Americas, Europe and East Asia & Pacific regions use more one billion m³ for industrial uses per year.
4. Yes, I try to reduce personal water consumption by:
 - turning off the tap when I brush my teeth
 - taking shorter showers
 - investing in water-efficient goods
5. I try to reduce my indirect water consumption by:
 - buying only the food you can eat before it goes bad
 - Reduce, Reuse, and Recycle
6. Yes. Based on my own research on the topic, I became aware that about 70 percent of the planet's surface is covered with water. Without it, life on earth would be impossible. Yet, less than one percent of the planet's total water resources can be classified as accessible freshwater resources. Hence, although water is virtually abundant, as much as two-thirds of the global population may live in regions with limited access to freshwater resources by 2050, as the world's population is predicted to grow to reach 11.2 billion people by 2100.
7. The fashion industry relies heavily on water for its own survival. From the irrigation of cotton crops at one end of the supply chain to the domestic washing of clothes at the other, fashion is a thirsty business. I believe that the fashion industry can reduce its water footprint by:
 - opting for organic cotton.
 - investing in low-water jeans.
 - avoid using polyester
 - finding out where materials are sourced
 - being conscious about leather
8. Yes, I do. However, I am constantly trying to do my personal part to fight fast fashion and overconsumption habits by filling closets with fewer clothes, made with natural, renewable or recycled materials.
9. Yes. My personal favorite is ArmedAngels.
10. I believe that the fashion industry should get involved in tackling the issue of water scarcity by moving towards a circular economy with eco-design and sustainable sourcing at its heart. Moreover, circular thinking needs to be embedded within each company, with a focus not only on reducing water consumption but also in raw material production and product water use in people's homes.

Participant 10, female, 26 y/o, Berlin (xxv)

1. Yes, I am familiar with this issue but I don't hear a lot about it in the media (online). I do not search information related to this myself, I heard from my friends.
2. Yes, I heard about this concept.
3. Not exactly, but I know one person consumes way much more water than one can imagine. So a lot.
4. Yes, I try my best to reduce my water consumption. I take shorter showers (when I'm not depressed), I turn off the water while brushing my teeth and while doing the dishes. I try to reduce my consumption habits, so that I don't buy any clothing article that I don't really need, I drink tap water.
5. Yes, as mentioned above (question 4).
6. Yes, I find it intimidating because I am not completely aware of this fact. I heard it is bad and we will eventually have to face the consequences but unfortunately I cannot view this as my reality, therefore I am not able to act in a way that will slow down the extinction of freshwater...
7. Wow, a lot. But first they'll have to have a reason to do it. Otherwise, if the consumer continues to encourage their behavior and the governments don't implement strict measures, nothing will change. One measure could be the implementation of water consumption limit/product. In this way, the fashion industry will have to adapt and find new fabrics that do not require so much water for their production. At the same time, I think recycling (even if not the solution) could be also used (but I am not sure if this does also imply the use of a lot of water) as a measure.
8. Yes. But I cannot do a lot to change it since the options I could choose to reduce my water footprint are too expensive for me (student). In a few years, when I will be able to spend more for the clothes I wear, I will do it for sure. I also hope for more transparency in the fashion industry because me, as a consumer, I would never spend time in the store or online (extra) to research the amount of water used for the product I buy. I will have to be displayed everywhere, so that I see it and I am aware of it.
9. HM comes to my mind even though I just don't trust them. It's like feeling guilty for cheating your wife and then buying her an expensive gift, to clear your consciousness. That's HM. I wish I knew more, but as I said, I am in the process of giving up things I own and I am not looking for knowing new brands at the moment.
10. If they wanted, they could but why do it if it works like this as well? They could listen to their customer maybe and see which are his/her needs at the moment. We should not forget about the textile dyeing processes. Natural alternatives should be found and used. And yes, I think definitely they should get involved, since they are the 2nd most water consuming industry, right?

Appendix 3: Primary Focus Group

- **What is your opinion on cutting-edge natural fabrics (algae-based, freshwater-free, grown in a lab)?**

1: I am a sustainability advocate and try to teach my friends and other people I know about how important it is that we change our current habits. Personally I am very eager to try there new types of fabric! I am very excited about the HM collaboration with Renewcell and cannot wait to buy their first 100% recycled cotton jeans collection!

2: I think these new innovations will completely change the way fashion works and I want to be part of this new era. What (participant number 1) is saying about 100% recycled cotton sounds amazing and I want to know more about that.

4: I have heard about this new HM incentive and it's very controversial. The fact they are (and always have been) a fast-fashion company makes their environmentally positive actions to seem just PR or Marketing. I think what they're doing is great, but I also think they should completely change the way they operate instead of adding some sustainable bits to the massive waste they produce.

3: I agree with (part no 4). HM and other fast-fashion retailers who produce huge amounts of waste and greenhouse gases only want to jump on the sustainability wagon because they know the current supply chain is going to become irrelevant in a few years time. They are trying to solve an issue that they themselves are causing in the first place!

2: Completely agree with both of you, but think about it this way: By 2050 the world population is going to reach about 9 billion. What are we going to do then? We cannot continue to grow cotton (even if it is organic) or create synthetic fabrics, at this rate we won't have enough land surface to grow food, let alone cotton or other crops like that.

1: (Part No 2) is right. The future is not only about upcycling and reusing old products or giving them a new life. This is of course a really good approach, but it is not a solution. At some point those clothes are going to end up in landfills anyway so finding new alternatives that do

not harm the environment is very important. I think new cutting-edge inventions like algae fabrics sound great, but if we do not have a way to recycle them, they will end up as waste, just like the cotton clothes that are currently not being recycled.

4: Even if we do find new alternatives and manage to recycle everything we produce it would still take a lot on energy and resources! I think that we need to be more responsible and stop seeing impulse-buying and fast-fashion as normal.

- **Do you believe that freshwater scarcity will change the methods we use today to make clothes? Why?**

3: Freshwater Scarcity is influencing a lot of things and will definitely have an impact on the future of textiles in my opinion. There are a lot of projects to help at risk communities in dry areas, especially because lack of freshwater is not only impacting their health, but also their education (especially for young girls who are the main carriers of this precious resource). We all know how bad cotton is for the environment, but we keep producing and buying it. Why? Because there is no other alternative that can offer the same qualities and feel. When there will be a better alternative for the same price, that's when real change is going to come.

2: Fashion has long been under scrutiny for its environmentally damaging practices. Especially in the case of cotton production!! A lot of consumers in my generation (born 1996) do not want to support companies who do not care about anything else but making money. We have the buying power and we want to make the right choice.

4: I've recently read an article discussing what are the alternatives to cotton available today and what could the future bring. One very interesting thing that me and (the student) already talked about is algae. Not only are they abundant, but also grow extremely fast and some species do not need freshwater to grow. There is a lot of ongoing research into this subject and I believe it holds a lot of potential in ending water scarcity caused by cotton farming.

- **What do you think about using freshwater for fabric production? And do you think it should be completely eliminated from this process in the future?**

1: I think that eliminating freshwater from the production process should definitely be viewed as a goal, but if there are processes that can completely recycle the water used in manufacturing it would be good enough for me.

4: you're right, but if we don't strive to completely eliminate it, then we might end up using too much of it anyway.

3: Replacing cotton production and other natural raw materials with other fibres that do not require freshwater is a very interesting concept, but what will happen with those people who rely on farming to make a living?

4: The government should finance them to help make as shift from conventional to future techniques such as vertical farming and stuff.

2: This is only plausible in countries like the US, but what about poor developing countries that do not have the necessary resources to do this?

1: this is a very delicate subject and there is no right or wrong answer, I believe things will inevitably change and people will need to somehow adapt to this.

- **Would you wear fabrics made from innovative plant-based sources such as algae, oranges etc?**

1: Yes absolutely :) I have read that algae fabric is also good for the skin!

2: We need to move on from these conventional fabrics and fully embrace the next chapter!

4: Of course! I'm a huge fan!

3: Like everyone, yeah.

- **Would you support brands that aim to save freshwater resources?**

1: I would yeah, it's important nowadays to put your finances in what you believe in. I see a change in people's mentality about superficial things. We all want to look good, but if my T-shirt is made from that has been picked by a child or polluted the only water resource in the area then I do not want to have to do anything with it. We have the option choose well.

4: It really depends on how they promote themselves and these actions. If I feel they are only green washing to increase sales then no, I WON'T.

2: I would support them. All my jeans are now Levi's and I love that they try to save water resources through all the technologies they implemented in their production.

3: I agree with (part 4). There are a lot of brands out there that only use organic cotton for example because it is great for advertising. It really depends on the company and what they promote as their values. Generally, I would support brands that implement water efficient methods.

