Chapter 10
Greening the Blues—How Jeans Have Stood the Test of Time by Adapting Innovative, Forward-Thinking and Sustainable Production Practices

Marina Chahboune

Abstract The denim and jeans industry is a huge and powerful business segment that has proved over the past decade that it can take its responsibility and be a key driver for change for the apparel industry in general. The developments of substitutes for toxic chemicals and the invention of new, resource-saving technologies have lifted the possibility of sustainable practices to a new, never imagined level. This chapter is highlighting the best practices for applied sustainability, innovations and the latest developments in denim and jeans supply chains, from the choice of raw materials to utilization opportunities for used garments.

Keywords Sustainable jeans · Sustainable denim manufacturing · Environmentally friendly jeans production · Ecological footprint jeans · Lower impact denim · Eco-friendly jeans finishing · Jeans indigo dyeing

10.1 Introduction

Imagining a world without denim garments seems to be impossible nowadays: Blue jeans have reached global presence. Whenever Daniel Miller—author of the book *Global Denim*—went abroad, he started counting 100 random people who passed him on the street to see how many of them were wearing blue jeans. His survey resulted in the insight that "the majority of the people in the majority of the countries of the world are wearing blue jeans on any given day" (Miller and Woodward 2011). While jeans have become globally a favorite wardrobe staple and a constant in the trend-driven, ever-changing fashion world, the jeans trade itself has become an essential element of the apparel industry. Currently, the overall denim and jeans industry is valued at more than $57 billion with an expected growth rate of 6% by 2023, driven by higher consumer demand within emerging markets and the transformation from

A practitioner's perspective

M. Chahboune (✉)
Closed Loop Fashion, Darmstadt, Germany
e-mail: marina@closedloopfashion.com

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classical retail toward an e-commerce industry (Prescient and Strategic Intelligence 2018; Wang and Newbery 2018). These days, jeans are a lot more than simply a 100% cotton product: Blue jeans—commonly known as a durable, high-quality garment originally made from woven twill fabrics—have become a favorite wardrobe staple by constantly reinventing itself. Consumer demands on performance, style, fit, weight and design have changed the denim business completely, and denim has expanded its classic application area for trousers only to all parts of fashion such as casual and even athleisure wear.

Another key driver for change is an increasing awareness among consumers about the conventional jeans production's negative environmental impacts: "The denim industry has long been the subject of much sustainability scorn" (Styles 2018). Especially, facts such as the enormous water pollution and heavy usage of toxic chemicals are often cited by campaigners for pressurizing brands to finally integrate cleaner production methods (Styles 2018). In 2010, a Greenpeace report revealed the *dirty secret behind jeans* which has led to major efforts within the whole industry to mitigate its negative impacts. The report gave a critical insight into the unhuman working conditions and tremendous environmental pollution caused by jeans manufacturer in China's city Xintang—by that time known as the *Jeans capital of the world* with an annual production of over 260 million pairs of jeans (Greenpeace 2010). Life cycle assessments (LCAs), which are evaluating the environmental performance of products throughout the life cycle, have identified that over 60% of emissions actually occur within the production part of the supply chain (Levi Strauss and Co 2015). The main identified environmental hotspots are the raw material stage and the dyeing and finishing processes (Levi Strauss and Co 2015 and Ademe 2006). Especially, water has been recognized as an essential ingredient for these manufacturing stages, and the lack of access to sufficient water quantities would pose potential risks on ensuring future operations (Safaya et al. 2018). Nearly 20% of global waste water is produced by the fashion industry (United Nations 2018), 10% of global carbon emissions and 4% of the world's annual waste (Kerr and Landry 2017).

The United Nations Framework Convention on Climate Change (UNFCCC) report is addressing these alarming problems which are the Sustainable Development Goals with one of their central vision being to tackle two of the main negative effects of the current polluting production methods: waste and the excessive extraction of primary resources.

The United Nations Alliance for Sustainable Fashion was initiated to contribute to the achievement of the Sustainable Development Goals' targets (UN Fashion Alliance 2019).

The denim industry as one of the leading industries by production quantities within the apparel segment has understood its responsibility. The whole denim industry has seen a major shift in the past years attempting sustainable and ecologically responsible practices throughout the entire life cycle from cradle to the product's end of life by developing and adopting technologies and methods to lessen unnecessary negative environmental impacts without sacrificing trends and aesthetics.

Today, "no other garment represents the kind of forward-thinking innovation that the fashion industry needs as jeans" (Styles 2018). Disruptive technologies, new waterless dyeing and finishing methods, innovative fiber blends, product innovation and efficiency improvements have significantly reduced the former negative impact of denim and jeans production.

10.2 Fibers and Fabrics

Jeans traditionally made from pure cotton denim have a long history that can be tracked back as far as the seventeenth century. The most commonly used weaving technique for denim is the right-hand 3/1 twill made from an indigo-dyed warp and an undyed weft yarn, resulting in a blue fabric front side and a mainly whitish inside (Muthu 2017). The fabric surface shows the characteristic upward direction of the diagonal-lined twill running from lower left toward upper right. The denim fabric was originally developed to create durable, long-lasting workwear which resulted into the invention of the popular Levi Strauss jeans in 1873—a work pants that additionally convinced with copper rivets for strengthening the corners of the pockets (Balfour-Paul 2011). With the era of Hollywood in the 1930s, jeans saw its turning point shifting away from its former application toward becoming a global fashion item (Miller and Woodward 2011). While styles and fits started to change, the fabric remained as originally created. The invention of stretch fibers and fiber blends as well as new consumer demands for form-fitting styles, lighter fabric weights and technical performance has led to new and innovative fiber and fabric developments throughout the last decades that go beyond the traditional cotton twill known as denim. One of the early adopted key trends has been the incorporation of Elastane in the warp in small quantities about 2–4% within the total fiber composition to create body-flattering fits that give the wearer more agility and comfort compared to jeans formerly known fabric stiffness. That trend has changed the whole denim industry and culminated into fully stretch and super stretch fabrics that can even be applicated to active wear styles. By using elastomer spun in both warp and weft, developments have further led to bi-stretch denim for athleisure *jeans*. The latter has been a consequence of the lack of recovery of single-yarn stretch fabrics. Furthermore, fiber blends of cotton with polyester have gained widespread popularity to improve performance, providing great durability and abrasion resistance (Muthu 2017).

Cotton, known as a thirsty crop, is associated with excessive water use (Sandin and Peters 2018). In 2007, jeans *brand Levi Strauss & Co.* conducted the apparel industry's first-ever life cycle assessment (LCA) to analyze the entire life cycle impact of a pair of jeans including all stages of the life cycle from raw material extraction, materials processing, manufacture, transport, use, repair and maintenance, recycling and end of life (Laitala et al. 2018). The results uncovered that the greatest water and energy impact was in the areas of cotton cultivation and consumer care during the usage phase (Levi Strauss & Co 2015; Ademe 2006). The amount of required water for cotton varies greatly depending on cultivation region, rainfall, the origin of irrigation water and the type of irrigation technology (Ferrigno 2012).

Therefore, many brands started to integrate organically grown cotton or cotton from better agriculture practices and water management systems such as the *Better Cotton Initiative* (*BCI*) into their collection to lessen their impact on the environment. But shifting from the usage of conventional cotton to organic cotton alone will not be enough to tackle these future challenges.

With an estimated overall apparel consumption rising by 63%, from 62 million tons today to 102 million tons in 2030 and a growing world population toward an additional two billion people by 2050 and emerging markets, the industry will face an increasing demand for textile fibers, environmental pollution, shortage of resources and competition among industries on finite resources (Kerr and Landry 2017; Östlund et al. 2017) (Fig. 10.1).

The *Environmental Benchmark for fibers* developed by the former Dutch non-for-profit organization *Made-By* compares the environmental impact of the most commonly used fibers in the garment industry on parameters such as greenhouse gas emissions, human toxicity, eco-toxicity, energy and water consumption and land usage (Gardetti and Muthu 2017). Based on these parameters, each fiber is scored and classified from Class A to Class E. *Made-By* rates recycled cotton higher than organic cotton: Replacing 20% of cotton in denim fabrics with fibers from post-consumer sources can save up to 500 L per garment. Besides requiring less energy and water, as well as fewer chemicals than its virgin counterpart, recycled cotton also convinces with generating less greenhouse gas emissions during production (Chua 2018). The *Higg Materials Sustainability Index* (*MSI*) shows that the *Recover* yarns with recycled content of Spanish spinning mill *Hilaturas Ferre* make the "lowest-impact cotton yarns in the global market and generously outperform virgin equivalent yarns across all sustainability metrics" (Recover 2019). Unfortunately, the shredding process of pre- or post-consumer cotton waste is resulting in short-staple fibers which need to be blended with virgin, long-staple fibers in order to avoid low fabric quality outcomes. Besides the usage of recycled cotton, recycled polyester (rPET) derived from post-consumer waste such as plastic bottles has become common as well in the denim industry.

Making more informed raw material choices, such as blending cotton with low-impact fibers, can significantly reduce the jeans footprint. One of the latest fiber innovations which significantly improves the impact at the raw material stage by reducing the need to extract virgin raw materials is the *Lenzing Refibra*™ fiber—a new generation of TENCEL® fiber and the first cellulose fiber derived from post-industrial waste such as cotton scraps and wood, produced in the lyocell production process (Lenzing 2019). Well-known Italian denim weaving mill *Candiani* completely eliminated the usage of virgin materials for its *REGEN* denim series by adopting 50% *Refibra* blended with 50% pre-consumer recycled cotton in both its warp and weft. Furthermore, *Candiani* launched its *ReLAST* stretch denim line using a customized *Global Recycling Standard* (*GRS*) certified *Roica Eco-Smart* elastomer developed by Japanese mill *Asahi Kasei* (Candiani 2017).

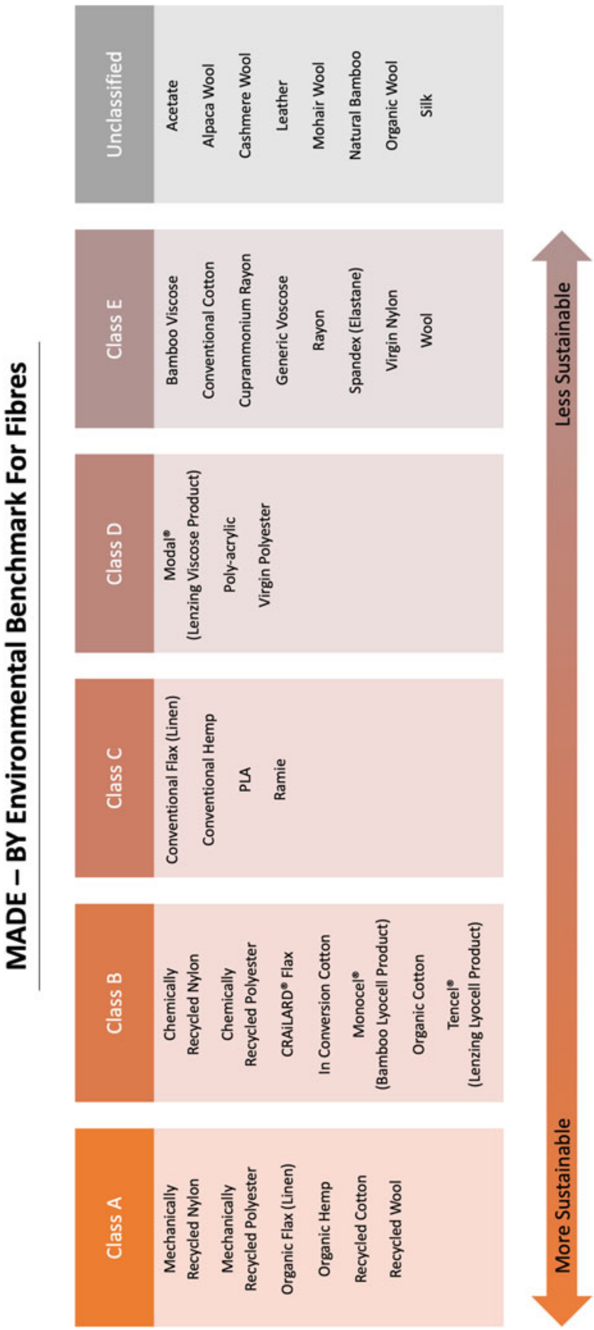

Fig. 10.1 Environmental benchmark for fibers by mMade-bBy (Illustration by D. Pircher)

10.3 Indigo Yarn Dyeing

The production step of yarn spinning is followed by dyeing, which for denim traditionally is a warp yarn dyeing process with indigo. The common procedure for it requires various preparation operations like prewetting, scouring and mercerizing to achieve a regular absorption of the dyestuff. Indigo itself is an insoluble vat dye which means that it cannot penetrate the cotton fiber until it is made soluble by the process of reduction. Reduction is basically a process where hydrogen is produced which opens up the indigo dye molecule allowing it to attach to a water molecule which carries the vat dye into the fiber (Mercer 2013). The common basic ingredients for the dyeing process are the indigo dyestuff, sodium hydroxide and hydrosulfite resulting in reactions that reduce indigo to the greenish-colored leuco-indigo, which can be applied to the yarns. This application process is continuously running alternately through the liquid dye bath and the so-called skyer to gradually oxidize. The air-oxidized yarns turn into the common indigo blue color again (Clariant 2012; Mercer 2013). The indigo blue color binds only to the surface and does not reach the core of the yarn which results into the subsequent characteristic jeans effect of color fading: As later, when the jeans is getting worn, the surface indigo slowly wears and washes off and the undyed white core appears (Velasquez 2017).

The whole dyeing process is very resource-intense, consuming up to several hundreds of liters of freshwater and energy. The significant amounts of chemicals and textile auxiliaries needed throughout the process are resulting in hazardous sludge and effluent that causes tremendous environmental pollution when released untreated into nature. The need to mitigate the negative impact of this traditional indigo dyeing process has been one of the key drivers toward more sustainable practices. Several leading denim manufacturers have developed competing, innovative new dyeing processes, and one can easily say that the process as applied today has changed remarkably.

Early attempts have been around an additional usage of sulfur dyes to achieve different cast of color shades while reducing costs. The sulfur dye can be applied to the yarns before the indigo application (sulfur bottom) or after (sulfur top) (Paul 2015). Chemical specialist *Archroma* has developed a range of low sulfur dyestuffs as well as the *Pad/ Sizing-Ox* dyeing process to reduce the consumption of water (Muthu 2017). *DyStar* in addition came up with its patented *Indigo Vat 40% solution*, achieving a significant reduction of the commonly needed amount of sodium hydrosulphite and water usage with this pre-reduced indigo liquid (DyStar 2019; Paul 2015). The latest experiments and developments are trying to not only reduce, but also to eliminate water consumption within the dyeing process nearly completely. Italian weaving mill *Candiani* is combining Kitotex with their in-house developed dyeing technology *Indigo Juice* to achieve a lower water footprint. While the usage of biodegradable Kitotex—a natural polymer derived from chitosan—replaces harmful pollutants and allows to cut down on water and chemicals and to operate at lower temperatures, Indigo Juice reduces the water, chemical and energy usage within the laundry process. During the dyeing process, the indigo is kept superficial on the yarn, therefore reducing the amount of water and energy needed to wash it down later in the jeans laundry process (Candiani 2017; Velasquez 2017).

Announced as breakthrough in the field of indigo dyeing is *IndigoZERO*™—a foam dye developed in the USA by the *Fiber and Biopolymer Research Institute of Texas Tech University* in collaboration with *Indigo Mill Designs*. This water-saving technique has been known for years but has only now been able to solve the former, hindering problematic indigo reaction with the air trapped inside the foam that had led to stop the dyestuff from penetrating the fiber, by replacing the oxygen with nitrogen (Mowbray 2018a, b). The whole process—from pre-reduced indigo production until the point where the yarns are ready for exposure to air for the oxidation—requires completely oxygen-free conditions. The technology works without a dye bath and without wastewater discharge, claiming to reduce water usage by up to 99% compared to the traditional indigo dyeing process, which results into production cost savings as well as significant savings of the precious resource water (Ethridge et al. 2018; Agarwal 2018). The first jeans collection made with foam dye is planned to hit the markets in 2019 by jeans brand *Wrangler* (Mowbray 2018a, b).

Another key innovation is *Smart-Indigo*™ developed by *Pure Denim* that is produced in an electrochemical process using indigo pigment, caustic soda, water and electricity only.

The enormes demand for water, energy and chemicals within the process of indigo yarn dyeing has led to an industry-wide effort in developing new and more efficient production methods. Stakeholders such as chemical and technology suppliers are coming up with a range of different, future-proof approaches to optimize the negative environmental footprint within the dyeing process by minimizing or even fully eliminating the usage of precious resources.

10.4 Finishing

There are two finishing steps within the jeans supply chain: the denim fabric finishing right after the weaving process that covers mainly mechanical treatments such as sanforizing, singeing or mercerizing and the garment finishing that is applied on the ready-made jeans mainly with chemical processes. Especially, the jeans finishing treatments that are needed, to give the jeans its worn-out look, used-effects like whiskers and other trendy appearances, often require toxic chemicals which are applied in wet processes. If done in the conventional way, the treatments applied within the finishing process often present potential health risks for workers, the environment through untreated effluent as well as later consumers wearing the treated jeans. In the conventional method, the indigo dyestuff gets bleached down from the jeans surface with the help of strong oxidative bleaching agents such as sodium hypochlorite (NaOCl) and potassium permanganate ($KMnO_4$). The amount of indigo removed from the denim is directly related to the amount of bleach added, the water temperature and the treatment processing time (Clariant 2012). Enormous water consumption, chemical usage and severe environmental pollution are the results.

Stonewash is a much-used method to achieve used looks, because of its ability to create varying degrees of abrasion in areas such as waistband, pockets, seams and body (Clariant 2012). For this process, pumice stones are added to the tumbler as abradants during garment washing. The degree of color fading depends on various factors such as the garment-to-stone ratio, washing time as well as machine load. There are many limitations and drawbacks associated with stonewashing, especially when it comes to wear and tear and damage to the washing tumblers and garments. In order to remove the pumice stones and their washed-off, sandy, dust particles from the garments and machines, several times of washing are required for proper cleansing. Furthermore, the quality of the abrasion process is difficult to control. One alternative that never really prevailed is synthetic stone made of abrasive material such as silicate or rubber. Their durability is much higher and therefore can be repeatedly applied. Alternatively, the stonewash process can be replaced by using enzyme-based washing technology. This would also help to conserve water, time and energy. Cellulase enzymes are natural proteins which are used in denim garment processing to create a stonewash-like look without actually using stones or at least by reducing the use of them. Unlike stonewash, cellulase acts primarily on removing the indigo from the fabric surface creating a clean and neat appearance without causing damage to the fibers (Damhus et al. 2013). Simple process handling, the obtaining of more reproducible effects and the minimization of softeners are additional advantages. For enzyme wash being a sustainable choice, the usage of genetically modified organism (GMO)—free enzymes—is advised. The finishing process in general undergoes a variety of rinsing—and tumble-drying steps in between the manual, mechanical or chemical treatments. The treatments are often harmful, labor intense, bearing potential risks in terms of human and environmental toxicity and consuming high amounts of water, which thereafter is also subject to contamination from the chemicals used during processing. Since water is known to become an increasingly scarce resource, especially replacing old washing tumblers with new, more efficient ones with better garment-to-liquid ratio and less water consumption have become standard for finishing laundries working with international brands. Leading suppliers involved within this production step have started to come up with more sustainable solutions and technologies for improved environmental performance (Roos 2016). One of the pioneers in this field is Spanish finishing technology manufacturer *Jeanologia* who has revolutionized formerly used finishing methods with the invention of several disruptive technologies such as laser, e-flow and ozone bleaching. The laser technology is an automated, digital tool to achieve effects on the garments and fabrics. It is a computer-controlled process, which enables the creation of patterns and used-effects which are otherwise created manually through hand scrubbing (Express Textile 2003). This ecologically and economically feasible technique achieves local abrasion and fabric breaks, used look effect, whiskers with excellent reproducibility and higher productivity. *Jeanologia's* most advanced laser machines like the *Twin Pro* are enabling more productivity, efficiency and an improvement of design management for large-scale productions of jeans. The machines are equipped with two laser heads working on both legs at the same time to increase production capacity for big quantities. The machines require very little maintenance and cleaning. The companies *G2* machine, is said to be the latest and most efficient technology for ozone bleaching. Supported by a generator, the machine takes oxygen (O_2) from the atmosphere and transforms it into ozone (O_3), liberating the particles inside the tumbler to produce results such as the elimination of indigo dye excess from the former dyeing process or the reproduction of the bleaching effects (Jeanologia 2019). Since ozone is toxic in higher concentrations, a closed system has to be secured at any time. At the end of the process, the ozone is breaking down again into pure oxygen. All of this is accomplished in a zero-discharge process without water or chemicals needed, therefore resulting in considerable resource, and cost savings after the investments on the machines are turned back. While the ozone technology has been a huge success, it took the industry a bit longer until they realized the huge potential of laser and even longer to integrate *Jeanologia's* nano-bubble technology *E-flow* into their processes. *E-flow* "breaks up" the surface of the garment, achieving soft hand feel and controlling shrinkage while using only minimal amounts of water. Oxygen is introduced into an electro-flow reactor and exposed to an electromechanical shock creating nano-bubbles and a flow of wet air to transfer chemicals onto the garments, such as pigments, coatings or softeners (Khalil 2016).

Jeans finishing is highly labor intense, and since the scandals of sandblasting went public, it is associated with unhuman and unhealthy working conditions, hazards and risks. While most of the new technology inventions focus on environmental and economic benefits, their automation has also resulted into factories being able to provide safer and healthier work environments that prevent accidents or even replacing labor with robotics for harmful production steps. Most chemical and mechanical treatments come with advantages as well as disadvantages, depending on how they are used and for which purposes. Bleaching down a dark blue denim garment to light blue with ozone makes little sense in terms of sustainability, since this process would require a good amount of energy. In this case, it would be preferable to produce a light blue denim fabric from the beginning to avoid excessive washing and bleaching. Sandblasting is a very good example for the industry having failed to set up proper standards and safety instructions. This treatment is based on blasting an abrasive material in granular, powdered or other form at very high speed and pressure onto the parts of the garment surface to achieve abrasion (Chandran et al. 2010). It is a purely mechanical process, not using any chemicals, nor water. But due to misusage and lack of workers' safety precautions, thousands of factory workers worldwide have fallen sick from the inhalation of the fine sand particles with an incurable lung disease, called silicosis, which leads to the disrepute of this treatment method that is prohibited today. It is necessary to evaluate each technology or processing method intensively and individually. On the outcome of this, individual safety arrangements, regulations and application areas can be defined to make this important production step safer in terms of human and environmental toxicology.

10.5 User Phase and End-of-Life Solutions

Jeans are of great popularity and besides t-shirts the most widely worn garment globally. With the current vast amounts of production quantities, it is necessary to find suitable ways to extend the product's life cycle and end-of-life solutions in order to avoid masses of waste.

The user phase is impacting the product footprint of jeans enormously and therefore offers a great opportunity to reduce its credentials: The biggest part of carbon emissions occurs during this phase as well as it contributes by a wide margin to water consumption. Clothing maintenance consists of repeated actions such as laundering and drying that contribute to high use of water, energy and chemicals. The longer the garment is used, the more important this phase will be for the overall environmental impact of the garment (Roos 2016). To handle the garments with better care during this phase can reduce the impact significantly (Ademe 2006). Washing a jeans every 10 times worn instead of every two times reduces energy, climate impact and water consumption by up to 80% as well as drying the garments on a washing line instead of using a tumble dryer (Levi Strauss and Co 2015). A washing machine cycle will use the same amount of energy regardless of whether it runs on full load or empty; therefore, it is preferable to always wash with full capacity. Furthermore, a washing machine uses electricity mainly for heating the water, which means energy can be easily conserved by washing with low temperatures (Black 2013). A case study done by ecologist Rachel McQueen from the *Canadian University Alberta* in 2011 proofed that it does not make a difference from a hygienic point of view, if one wears a pair of jeans unwashed for two weeks or a full year daily (Knowles 2016). McQueen took bacterial counts from a pair of jeans, which one of her students had worn for 15 months without washing. The result: The bacteria load on the jeans was surprisingly harmless and only comprised normal skin bacteria. McQueen discovered that bacteria growth was virtually the same from the jeans after 15 months with no washing, compared to two weeks after being washed (Cotter 2011; Knowles 2016). So far, adopting a sustainable user's behavior at the utilization and disposal phase was under the full responsibility of the consumer himself. Brands had very little chance to influence at this stage, besides advising on a suitable washing care behavior. Only recently, denim brands started to pay attention to the garment disposal phase, to include this stage within their operations and to promote sustainable practices that involve the consumer. With new developments for fiber sorting and recycling technologies, denim post-consumer waste has become an attractive input for the raw material stage. Jeans brands start initiating take-back systems at their point of sales (POS) for used garments to not lose this valuable resource to landfill that can then be either turned into second-hand items, upcycled into new products or used for fiber recycling. Swedish brand *Nudie Jeans* as pioneer in this field already offers a wide range of denims in their collection containing partly recycled fibers content from post-consumer waste. Denim garments which they receive back from their costumers that are still in good, wearable conditions are washed and if needed repaired just to make their way back into sales as second-hand denims (Nudie Jeans Co 2019). The trend to include a certain percentage of recycled content into the fabric composition has already been adopted by some of the big players in the industry such as Swedish fast-fashion retailer *H&M*. Dutch brand *Mud Jeans* has built his whole business model around circularity right from the beginning, making sure that the majority of their jeans are returned for further usage after the consumer does not need them any longer. The brand offers a wide range of denims for leasing. After leasing their jeans for a period of 12 months, the consumer can decide to either switch to a new pair or to keep them until they are worn out. The jeans taken back are shredded into new fiber input, and the brand claims that at this point, their collections already contain up to 40% of post-consumer recycled cotton per jeans (Mud Jeans 2019). Fashion retailer *C&A* has taken the idea of circular economy to its highest level by developing a cradle-to-cradle solution: In partnership with *Fashion for Good,* they developed the first-ever Cradle to Cradle (C2C) Certified Gold-level jeans, by including the strict environmental requirements of the certification, which evaluates garments for human and environmental health, recyclability or biodegradability, energy and water requirements as well as social fairness. The development phase has taken more than a year and has covered all aspects along the supply chain such as material health, material reutilization, renewable energy and carbon management, water stewardship and social fairness (Fashion for Good 2018). The key challenge identified throughout the project for creating Cradle to Cradle Certified jeans is the complexity of the network of partners involved as well as the still limited availability of components and chemicals. (Fashion for Good 2018).

Much of the impact from clothing arises during production and processing. Extending the life of clothing through more durable design, and enabling reuse, repair and recycling, helps to reduce this impact, as production from virgin raw materials has a higher environmental burden than reuse or repair (Gray 2017).

10.6 Forecast and Future Trends

The denim and jeans industry is a huge and powerful business segment that has proved over the past decade that it can take its responsibility and be a key driver for change for the apparel industry in general. The developments of substitutes for toxic chemicals and the invention of new, resource-saving technologies have lifted the possibility of sustainable practices to a new, never imagined level. Combining innovative solutions throughout the entire supply chain, the prospect of water-free denim production, which *Jeanologia* estimates for 2025, could become a reality. By integrating tracking systems to obtain full transparency along all production steps, material compositions and process chemicals could be better identified for the ease of fiber recycling or other suitable end-of-life solutions on an industrial scale. Inventions such as DNA molecular tagging are already under way today and would provide the industry with an effective tool to authenticate denim. Brands and their suppliers are realizing socioeconomic benefits that can immensely change the way we produce and consume jeans. Industry leaders in terms of production quantities and sustainability—such as Vietnam-based garment and finishing mill *Saitex*, who has set the benchmark and is claimed to be the *world's cleanest denim laundry*—are already today convincing with a LEED-certified production facility that recycles 98% of its water, relies on alternative energy sources and repurposes its by-products. Workforce, especially in high-risk process steps such as the application of chemicals, will be replaced by robotics, while companies are introducing fully automatic sewing lines and creative software systems for digitizing the process of designing jeans, to optimize efficiency and the challenge of increasing labor costs. Jeans have stood the test of time and with its ability to constantly reinvent itself and with its speed in adopting sustainable practices have the potential to lead the fashion industry into a new era of clothes manufacturing on all levels.

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