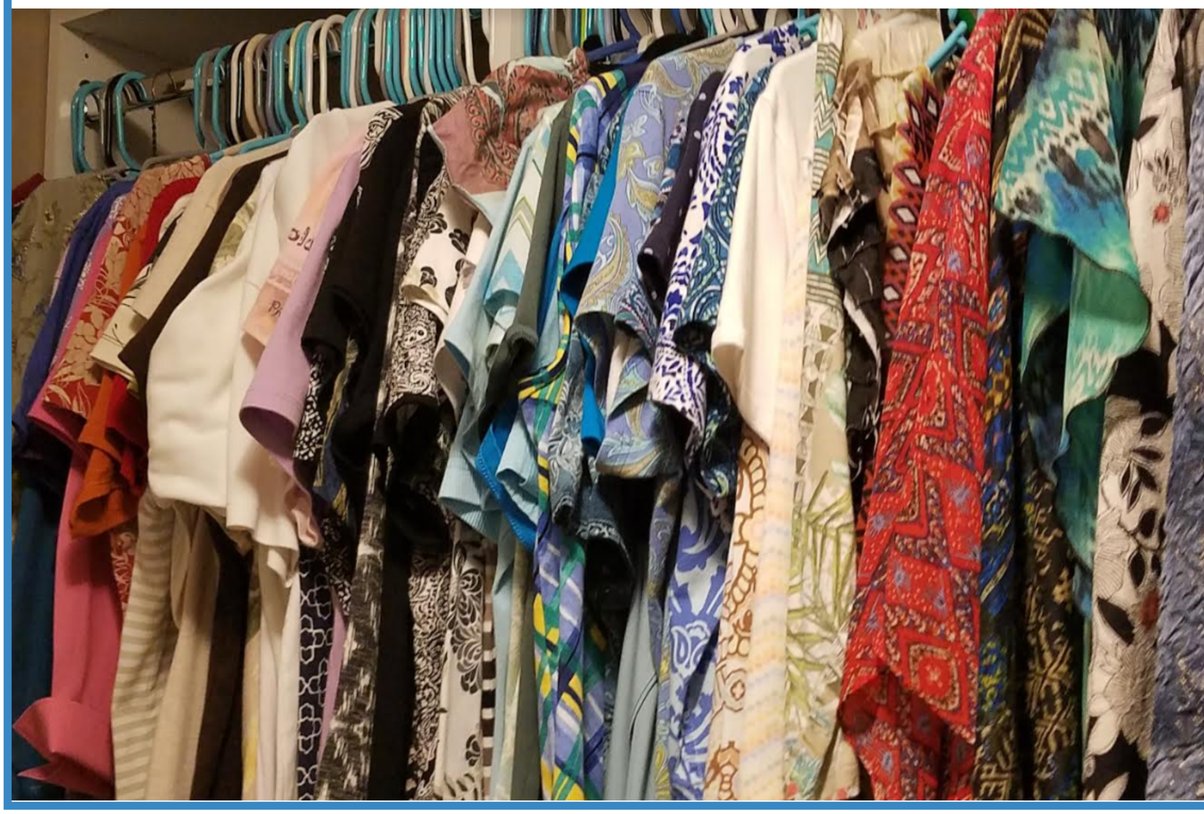
Dovetail Partners Consuming Responsibly Report No. 13

An Examination of Environmental Impacts of Clothing Manufacture, Purchase, Use, and Disposal



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November 11, 2019

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An Examination of Environmental Impacts of Clothing Manufacture, Purchase, Use, and Disposal

Executive Summary

Clothing production is dominated by two types of fiber – synthetic (principally polyester) and cotton. These two types of fiber together account for over 80% of fiber used in clothing manufacture.

Synthetics are derived from non-renewable petroleum, coal, and natural gas, are not recyclable, and are a major source of microplastics in the oceans. Cotton production, on the other hand, requires huge quantities of water, accounts for a significant portion of pesticide use globally, and requires greater use of both water and energy for laundering through its life cycle than do synthetics. Cotton fiber, however, can be recovered for a variety of uses after being made into textiles. Other natural fibers, which include both animal fiber (primarily wool) and fiber from a variety of crops, including flax, wood, and bamboo, account for 5-6% of clothing fiber.

A major clothing industry issue is the relatively recent practice of marketing low-cost, short-lived fashions, leading to rising rates of both per capita clothing consumption and discards. Coupled with the reality that countries that have long been outlets for used clothing are beginning to reject shipments, current apparel industry trends threaten to overwhelm used clothing outlets while also increasing landfill volume.

Consumers can help to reverse recent trends by limiting purchases, avoiding trendy short-life fashion trends, and helping others, especially children, understand the impacts. When buying new clothes, lower impacts can be realized by purchasing recycled-content items, or items containing Tencel®, BCI™, or organic cotton products. Checking out second-hand clothing outlets before buying new is another great option.

The Global Garment Industry

From Fiber to Fashion – A Massive Industry

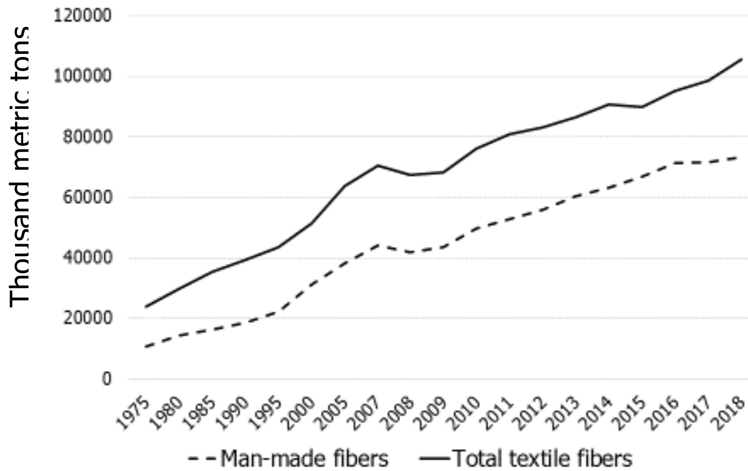
The garment industry globally consumed over 100 million tons of clothing fiber in 2018, an all-time record. The industry is large, and diverse, with fibers obtained from plants (including trees), animals, and increasingly from petroleum and other fossil fuels.

Worldwide production of textile fiber – indicative of clothing production – has risen at more than twice the rate of population growth for over four decades, with the rate of growth rising even more rapidly in recent years (Figure 1). In addition to increasing population, growing clothing consumption is driven by rapid economic growth in developing nations, a drop in clothing prices, and by a relatively recent global phenomenon – *fast fashion*.

Fast fashion is characterized by frequent development of new styles, partially by copying styles from high-end fashion shows, mass producing those fashions, and selling at low prices. Low quality materials are often used as garments are not intended for long-term use. A report prepared by the European Parliamentary Research service (2019) noted that the average number of collections released by European apparel companies per year had increased sharply over a period of little more than a decade (on average from two to five), with two manufacturers offering 24 new clothing collections each year, and another between 12 and 16.

The result, according to the EU report, is that consumers increasingly see cheap clothing items as perishable goods which are commonly thrown away after wearing only seven or eight times.[1]

Figure 1
Global Production of Textile Fibers, 1975-2018



Source: Statista (Garside) (2019)

Asia, and primarily China, account for the greatest quantity of clothing fiber production. China is by far the leading producer of synthetic clothing fiber (principally polyester) and is also the world's largest producer of cotton, the dominant fiber among natural clothing fibers. The U.S. ranks third in cotton production globally.

Clothing manufacture is more decentralized than is fiber production. While China again dominates, major producers include the EU, India, the U.S., Mexico, and several Asian nations including Vietnam, Bangladesh, South Korea, Turkey, Pakistan, Cambodia, and Indonesia.

Clothing Consumption

On the consumption side, China again dominates world statistics, accounting for the purchase of 40 billion clothing units in 2017, more than twice that of any other country, and almost 7 times more than India. Western Europe and the U.S. are also major consumers on the basis of number of clothing units sold.

While China tops the list of total clothing items purchased, it is the most economically developed nations that top the list of clothing consumption on a per-capita basis. Nations with the greatest clothing consumption per-capita are the U.S., the EU, Australia, Japan, and Canada. The differences between nations are large, but narrowing. A 2018 study found an average of 53 clothing items purchased annually per capita in the U.S. as compared to 30 in China.[2] However, data indicates that U.S. per capita consumption of new clothing peaked in 2006 at about 70 items per capita, trending sharply downward during the 2007-2010 economic recession through the present.[3]

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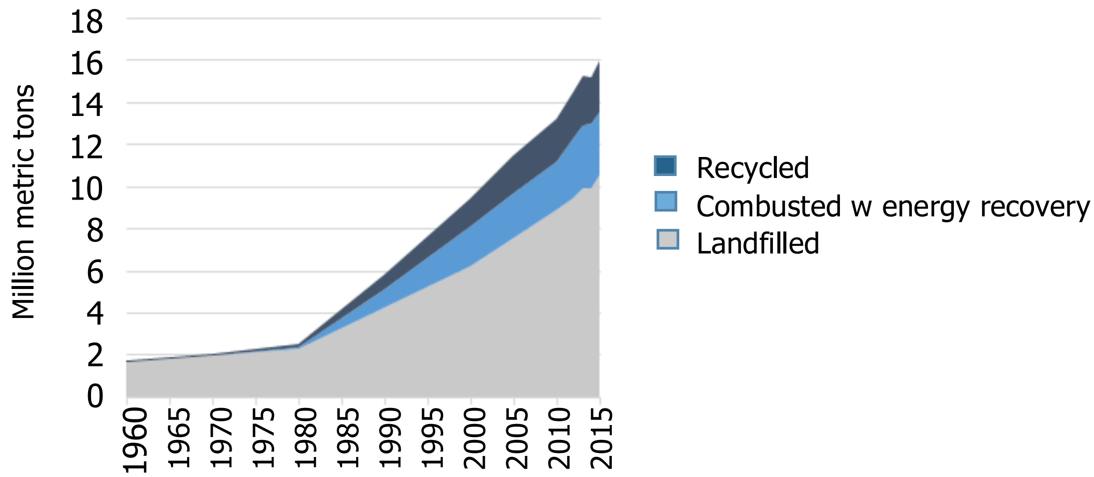
[1] Šajn 2019
[2] Common Objective (2018)
[3] Bain (2018)

Clothing Discard Issues

Disposal of clothing has become an issue globally. The volume of clothing discarded to the waste stream by Americans doubled from 8 million to about 16 million tons annually between 1995 and 2015, with the latter translating to 80 pounds per person. The majority of discarded clothing in the U.S. is landfilled or combusted for energy recovery. Relatively small, but growing volumes, are captured for recycling or reuse (Figure 2). The situation globally is similar.

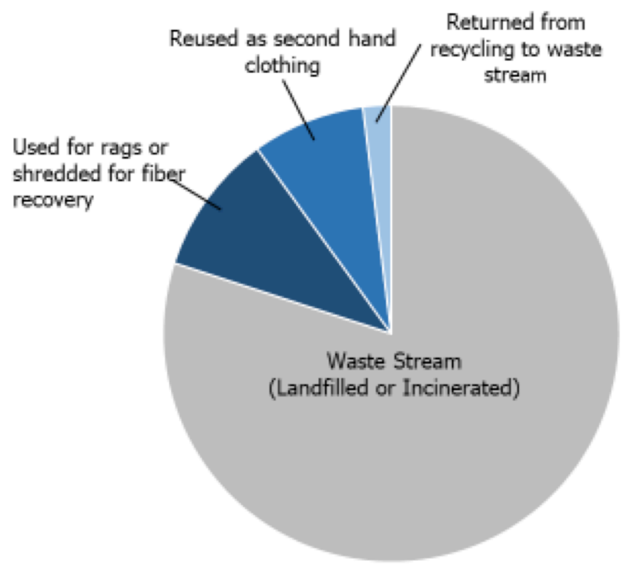
Figure 2
Textile Waste Management in the United States, 1960-2015



Source: U.S. Environmental Protection Agency (2019)

The organization Common Objective (CO) reports that four-fifths of discarded clothing globally goes into the waste stream, and one-fifth into the recycling and sorting streams. Half of that one-fifth is recycled (i.e. shredded with fiber recovery or used as industrial rags), 40% is re-used as second-hand clothing, and the remaining 10% ends up in the waste stream (Figure 3). Overall, 57% of clothing discarded worldwide is estimated to wind up in landfills, and most of the rest is incinerated.

Figure 3
Fate of Discarded Clothing Globally



Source: Common Objective (2018)

Reuse of second hand clothing occurs primarily in developing countries, and millions of tons of used clothing is shipped to developing countries each year. Recent developments may reduce the second-hand use of discarded clothing and send more clothing into the waste stream. A group of East African nations have enacted bans on importation of second-hand clothing, citing adverse impacts on economic development (i.e. development of local garment industries) and local tradition.[4] Discarded clothing imports are also reported to pose similar problems for India[5], which could further restrict outlets for second-hand garments.

Environmental Impacts of Clothing Production

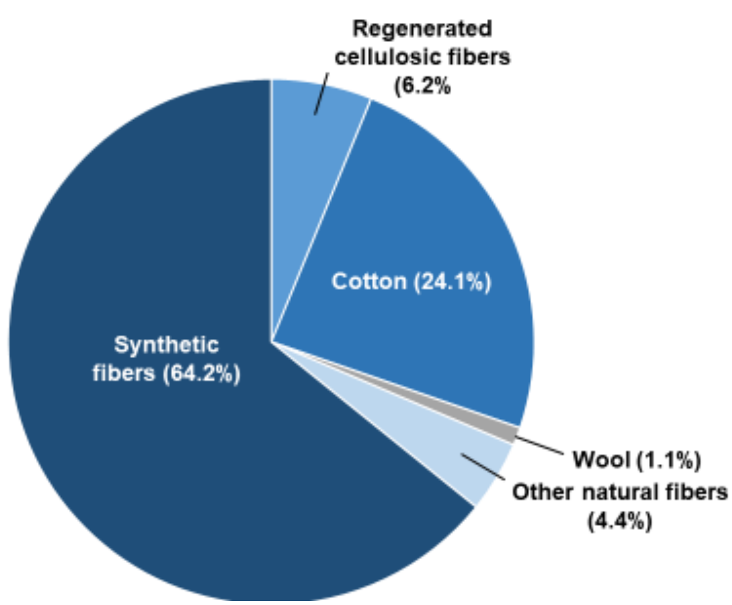
In 2015, the global textiles and clothing industry consumed an estimated 2.1 trillion gallons (79 billion m^3) of water, generated 1.7 billion metric tons of CO_2 emissions (approximately 4.6% of total global carbon emissions), and was responsible for 92 million metric tons of waste. Without changes in industry practices, estimates indicate that these numbers will increase by at least 50% by 2030.[6]

Production of Clothing Fiber

One determinant of overall environmental impact from clothing is the type of fiber used in production. Fiber used in clothing production ranges from synthetics to natural fibers, to fibers chemically regenerated from naturally produced cellulose.

Of the estimated 106 metric tons of clothing fiber produced globally in 2018, approximately 64% was synthetic fiber, 30% was natural fiber, and 6% was regenerated fiber derived from wood. Synthetics include polyester (about 90% of synthetics), polyamide (principally nylon), acrylic, and polyurethane (spandex/elastane) fiber, all of which are derived from fossil fuels. Natural fiber is primarily cotton (81% of natural textile fiber); but also includes wool, silk, flax, bamboo, hemp, and a variety of other plant-derived fibers. Regenerated fibers include viscose, modal, and lyocell rayon (Figure 4).

Figure 4
Global Fiber Consumption in 2017 by Type of Fiber (%)



Source: Lenzig Group (2017), Townsend (2019)

[4] Batlanki (2017), Sandin and Peters (2018)
[5] Chitrakorn 2017
[6] Global Fashion Agenda/Boston Consulting Group (2017)

Synthetic Fiber

Polyester is the most widely used synthetic fiber and was first used in making cloth in 1941. The development, by British scientists, was inspired by wartime shortages of cotton. Dupont purchased rights to produce polyester in the U.S. in 1946 [7]. Polyester is used both by itself, and in combination with other synthetic and natural fibers, in making clothing.

Polyester is made from coal, petroleum, air, and water in a high temperature environment under a vacuum. While still hot, the resulting long-chain polymers are extruded into long fibers that are further stretched from their original length. These long fibers are then combined into threads through a spinning process. Dyeing of fiber can be achieved prior to spinning, or in higher impact processes at a later stage.

Production processes for other synthetic fibers are similar to those for polyester. Of the four principal synthetics (polyester, nylon, acrylics, and elastane), production of nylon results in the greatest energy consumption and carbon emissions. For example, in comparison to polyester, production of nylon fabric of the same density requires about 15% more energy and 40% greater carbon emissions.[8]

Comparisons of energy consumption in production of polyester and cotton fabrics show that energy required to produce a kilogram of polyester is 1.4-2.2 times that of producing a kilogram of cotton.[9] Differences become greater as these basic materials are transformed into an article of clothing. The quantity of energy required to produce one kilogram of apparel[10] made of polyester, for instance, is about three times that of an equal quantity of cotton. There is a similar difference in CO_2-e emissions. However, when energy consumption and carbon emissions are considered within the context of the entire life cycle of garments, there is little difference between cotton and polyester.[11] This is in part due to the fact that energy consumption in the use phase tends to be lower for polyester clothing since synthetics absorb less water, are more resistant to soiling, require less water for washing, dry quickly, and need little or no ironing.[12]

There is a significant difference between cotton and polyester with regard to water use. Polyester has a substantially lower water footprint than cotton, particularly in the production phase. Water requirements for producing cotton fiber are hundreds of times greater than for producing polyester fiber.

The most daunting aspect of synthetic fiber, and its use in clothing, is that clothing made of synthetic fiber has been found to be a significant source of microplastic fibers now found throughout the world's oceans and other water bodies. Numerous studies have shown that microplastics are released with each washing, with as many as 700,000 fibers released to water from one laundry load of polyester clothing. Estimates further indicate that washing clothes that contain synthetic fiber results in the addition of approximately 500,000 metric tons of plastic microfibers to ocean waters every year.[13] In response to numerous reports regarding

[7] Quatr.us (2018)
[8] Van der Velden et al. (2014)
[9] Shen and Patel (2008), Cushman-Roisin Cremonini (2019)
[10] Equivalent to about 5 cotton shirts and slightly fewer than 5 polyester shirts.
[11] Moazzem et al. (2018)
[12] Shen and Patel (2008), Laitala et al. (2018), Šajn (2019)
[13] Laitala et al. (2018), Speranskaya et al. (2018); Šajn (2019)

microplastic pollution, one group of scientists reported finding far more natural fibers in the world's waters than synthetic fibers.[14] They noted that while there is a general consensus that the biodegradability of natural fiber reduces the environmental threat, the prevalence of this material in water supplies warrants further examination.

Clothing made of synthetic fiber has been found to be a significant source of microplastic fibers now found throughout the world's oceans. Washing clothes that contain synthetic fiber results in the addition of approximately 500,000 metric tons of plastic microfibers to ocean waters every year.

The synthetic fiber industry is currently experimenting with bio-based polyester (also known as biosynthetics), made at least partly from renewable resources such as corn, sugarcane, beet or plant oils. While potentially decreasing dependence on fossil fuels as a raw material source, biosynthetics will not necessarily biodegrade over time unless specifically designed to do so.

Cotton and Other Natural Fiber

Cotton was once the dominant fiber in all global textile production. In 1950, cotton accounted for 71% of *all* textile fibers globally, while synthetics accounted for less than 1% of textile fiber. Cotton continues to account for over three quarters of *natural* fiber production, and a quarter of textile fiber overall. All other natural fibers account for about 5% of fiber used in textile manufacturing. Following the harvest of cotton, the fiber is transported to yarn manufacturers where fiber is spun into yarn. As with synthetics, dyeing may occur before or after spinning.

A large share of the environmental impact of the cotton and natural fiber textile and clothing industry occurs in the growing of fiber crops. This is especially true of cotton, a crop that requires the use of irrigation as well as inordinate quantities of pesticides. Production of cotton requires an average of 8,000-9,000 pounds of water per pound of cotton produced (8-9 metric tons per kg)[15], to as high as 29,000 pounds per pound (29 metric tons per kg).[16] High water requirements for cotton production contribute to high water stress in many producing regions.[17] In addition, pesticide requirements per area of cropland are high. According to statistics from the cotton industry, cotton is planted on about 3% of the world's cropland but accounts for 16-18% of all pesticides used worldwide.[18] Some success in reducing pesticide use has been achieved through the use of genetically modified cotton.[19]

Production of cotton requires enormous quantities of water, contributing to high water stress in many producing regions. Organic cotton production requires far less water, but currently organic accounts for less than ½ of 1 percent of cotton production.

[14] Stanton et al. (2019)
[15] Cushman-Roisin and Cremonini (2019)
[16] Kalliala and Nousiainen (1999)
[17] Chapagain at al. (2006)
[18] International Cotton Advisory Committee (2018)
[19] Rocha-Munive (2018)

In an attempt to reduce the high environmental impact of cotton production, a non-profit the Better Cotton Initiative (BCI) was launched in 2009 for the purpose of providing training on sustainable cotton farming practices to farmers in cotton-producing countries around the world. BCI also licenses farmers who agree to adhere to sustainable practices and to periodic assessments of farm operations. BCI licensed cotton accounted for 19% of global cotton production in 2018. Another segment of the industry is shifting toward production of organic cotton, presently accounting for about 0.43% of global production. Table 1 summarizes results of an ISO-compliant life cycle assessment of conventional versus organic cotton. Potential reduction of impacts is driven by reduced or avoided agricultural inputs in organic cotton systems such as fertilizer and pesticides, reduced irrigation and associated need for power to pumps, and reduced tractor operations.

Both the BCI and organic approaches aim to reduce environmental impacts of cotton production. A significant difference in these two approaches is that BCI cotton seeks to minimize the use of chemical fertilizer, pesticides and herbicides, but does not prohibit their use as is the case with organic cotton. Farmers licensed under the BCI program are also allowed to plant GMO cotton, whereas GMOs are strictly prohibited in certified organic production systems.

Table 1
Findings of Life Cycle Assessments of Conventional vs. Organic Cotton Production

	Conventional Cotton	Organic Cotton	Reduction from producing organic fiber
Primary energy consumption (MJ/1,000 kg lint)	15,000	5,800	62%
Global warming potential (kg of CO_2 equivalent)	1,808	978	46%
Blue water consumption (m^3/1,000 kg)*	2,120	182	91%
Acidification (kg SO_2 equiv)	18.7	5.7	70%
Eutrophication (kg PO43 equiv. / 1000kg fiber)	3.8	2.8	26%

* The term "blue water" refers to use of either ground or surface water used for irrigation of crops. The term differentiates this source of water from "green water" – that water which is provided through rainfall.

Source: PE International (2014)

Regenerated Cellulosic Fiber

There are three basic varieties of regenerated cellulosic fiber used in textiles today. Regenerated cellulose fiber is produced in the form of viscose rayon, modal rayon, and lyocell. All are forms of rayon, made primarily from cellulose obtained from wood or bamboo. Other sources of plant cellulose can also be used. In making these products, plant-produced fiber is broken down through the use of chemicals, and then reformed. Such fiber is generally referred to as regenerated cellulose, or sometimes, semi-synthetic fiber.

Viscose rayon was first produced and sold in the U.S. in 1911, marketed as "artificial silk." The name "rayon" was adopted in 1924.[20] As a fabric, rayon has long been used in making home furnishings and soft goods such as draperies, bedspreads, and upholstered furniture, in part because of its colorfastness and resistance to fading. It has also been used in making clothing, although low wet strength (which makes it prone to shrinking and stretching), tendency to wrinkle, and dry cleaning requirements have limited its use.

Modal rayon was developed in Japan in the early 1950s. While made in a very similar process to viscose rayon, regenerated model fibers are stretched following formation to increase their molecular alignment. Worldwide marketing as a clothing fiber began in the 1990s. Known for its extraordinary softness and high wet strength, modal can be machine washed and tumble dried without shrinkage, and also wears well over time. Modal is also 50% more water absorbent than cotton, a property that enhances skin comfort and wrinkle recovery and resists static build-up. Like viscose rayon, modal is color-fast and retains strength while maintaining its soft feel. It is used in clothing of all kinds, including underwear, and in a number of other products, either by itself or in blends with other types of fiber.

Lyocell, the latest form of rayon, uses a different solvent than is used in other rayon processes, and production features closed loop processing of chemicals. The fiber has the ability to quickly absorb liquid, then to quickly dry while providing resistance to development of odors. Lyocell fiber is most commonly made from wood or bamboo, with the greatest volume of wood-derived fiber sold under the brand name Tencel®.

Several studies have examined environmental impacts of regenerated cellulosic fiber. One of the most comprehensive of these examined various types of regenerated cellulosic fiber in comparison to conventional cotton and two types of synthetic fiber. Comparison was made on the basis of one metric ton of staple fiber, cradle to factory gate.[21]

In comparison to regenerated cellulose, cotton production was found to require less energy (8-52% less). However, cotton also required:

- 20 to 500% more land area for growing of fiber crops
- 100-500 times more water than for regenerated cellulose if cooling water in regenerated cellulose production is excluded and 10-20 times more water when cooling water is included in calculations
- substantially greater environmental impact with respect to all other environmental impact measures studied

Comparing regenerated cellulosic fiber to the synthetic fibers (PP and PET[22]), synthetics were found to require:

- significantly greater fossil fuel energy inputs, and generally greater cumulative energy
- greater global warming potential
- less land area
- less process and cooling water
- greater abiotic depletion and human toxicity impact measures, but comparable or lower impact measures in all other impact categories examined

[20] Chen and Burns (2006)
[21] Shen and Patel (2010)
[22] Polypropylene and Polyethylene terephthalate

Another study[23] examined, through use of life cycle assessment, replacement of cotton with Tencel® in the manufacture of a T-shirt, a pair of jeans, and a hospital uniform. A key finding was that use of Tencel® instead of cotton would result in a greater than 95% reduction of water consumption. Report authors concluded that the magnitude of reduction of water use impacts resulting from use of biomass resources (e.g. wood) warrants increased investment in forest cellulosic fibers on the part of the textile industry.

Yet another study[24] involved a comparative life cycle assessment of eight viscose rayon operations, one lyocell fiber production operation, and flax production. In this case, the lowest impact operations were found to be producing flax (used in making linen), and a mill that utilizes cotton recovered from recycled clothing in making viscose rayon.

Production of Apparel

The first step in clothing manufacture is to weave threads or yarn into fabrics. These are sometimes chemically treated, or further processed to give fabrics added properties such as strength, shine, or water resistance.

Apparel production, which involves cutting, sewing, finishing, inspection, and marking, concludes the sequence. Production stages vary depending on the fiber, fabric and end product.[25]

Fabric loss in the cutting stage is a significant issue. A study of fabric wastages in knit T-shirt manufacturing in Bangladesh[26] reported that on average 26.5% of fabric was wasted at various stages. Another report examined fabric loss in production of a wide range of clothing items, finding losses of 13-18% were common.[27]

Beyond environmental issues, the clothing and textile industry has a long history of using exploitive labor practices as documented in multiple reports over many decades. A number of third-party certification programs provide oversight of production facilities and supply chains to ensure adherence to global labor practices. Among these are Fairtrade International, Fairtrade USA, SA 8000, Ethically Handcrafted, and WRAP (Worldwide Responsible Accreditation Production).

Clothing Reuse and Recycling

Reuse of Clothing

Used clothing is commonly handed down for reuse, taken to consignment stores for resale, or sold informally through garage and rummage sales. There is no data as to clothing reuse through hand-me-downs or of quantities of clothing which trade hands in informal sales. Regarding the latter, judging by garage sale activity in the Minneapolis/St. Paul metropolitan area, where such sales are prolific in the summer months, the volume is substantial.

Often, used clothing that does not sell in a garage sale, or which is otherwise slated for discard, is taken to clothing donation bins or centers rather than thrown in the trash. This volume has

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[23] Roos et al. (2015)
[24] Schultz, T. and Suresh (2017)
[25] Moazzem et al. (2018), Šajn (2019)
[26] Rahman and Haque (2016)
[27] Beton et al. (2019)

been estimated at 1.4 million tons annually for the U.S. and 1.5-2.0 million tons annually for the E.U.[28] Some donated clothing is resold locally, such as by Goodwill in the U.S., while other clothing is sold in bulk and exported to developing countries. The 1.4 million ton estimate for the collection of used clothing in the US represents less than 10% of the nearly 16 million tons of annual clothing discards reported by the U.S. Environmental Protection Agency (Figure 2).

As reported by Cottonworks™, a number of companies including Columbia, The North Face, and Patagonia accept used clothing from customers for repurposing. Patagonia also has a program for repairing used Patagonia brand clothing to extend product life.

The latest twist in clothing reuse is a series of decisions by major retailers to begin selling used clothing in their retail stores. Macy's, H & M, Nieman Marcus, J.C. Penney, and Banana Republic are among the list of retail giants to announce addition of used apparel to the product lines sold in their stores. A growing list of retailers are also now offering "Try Before Your Buy" programs which allow customers to rent clothing items with an option to buy.[29]

Recycling of Clothing

Synthetics

Polyester and other synthetic clothing is sometimes advertised as recyclable. While this is theoretically possible, virtually no clothing made of synthetic fiber is recycled. Instead, most synthetic fiber clothing is incinerated (with and without energy recovery) or ends up in landfills at the end of use. Synthetic fabrics advertised as recycled or made of recycled content are produced from recycling of plastic from plastic drink containers. Once made into fabric, however, recovery and recycling becomes highly unlikely.

Recent research could dramatically improve prospects for synthetic fiber recycling. Scientists at the Hong Kong Research Institute of Textiles and Apparel have reportedly developed a method for separating cotton from polyester in cotton-polyester blended fabrics, allowing reuse of polyester fibers in new garment manufacture.[30] The new technology is in a pilot phase.

Cotton

Cotton scraps generated in garment production (pre-consumer scraps) are often recovered, shredded, and separated into fiber, with fiber then re-used in textile production. Post-consumer recycling of clothing for reuse of fiber in clothing is less common. The process of fiber recovery damages and shortens fibers, limiting potential uses. For this reason, the recycled content in cotton clothing and other articles containing recycled cotton fiber is generally limited to a maximum of 30%.

The Miljögiraff organization[31] examined the potential environmental benefits of recycling post-consumer cotton clothing. They found embodied energy to be essentially the same as for organic cotton, but estimated global warming potential at less than a third of organic. Impact estimates for acidification and eutrophication were also found to be lower than for organic cotton. Water use requirements, however, were estimated at more than double that of organic

[28] Lu (2015)
[29] Mahoney (2019)
[30] Koh (2017)
[31] Miljögiraff (2016)

cotton, but only a fourth of conventionally produced cotton. These numbers suggest considerable potential for reducing cotton production impacts, although it is important to remember that fiber produced in this way is limited in use compared to new fiber.

A manufacturing plant in Sweden is using a different approach to cotton fiber recycling than suggested by Miljögiraff. In this case, cotton recovered from clothing is being used as raw material in a viscose rayon plant that regenerates cellulosic fiber. A previously mentioned life cycle assessment that involved examination of a number of viscose, modal, lyocell production facilities[32] found this operation yielded the lowest environmental impact across all impact measures in comparison to all other regenerated cellulose operations.

While recycling of post-consumer clothing for reuse in clothing production is limited, recovered clothing is commonly used for other purposes. As earlier reported, a portion of donated clothing is resold for continued use (about half of donated clothing), some is used as rags for industrial purposes (about 30 percent), and some is shredded for fiber recovery (about 20 percent). Recovered fiber is used in a wide variety of applications including pillow or car seat stuffing, production of wet wipes, carpet and mattress pads, and fiber reinforcement in concrete.

Summary

The volume of used clothing is increasing as low-cost, short-lived fashion lines drive rising consumption. Made increasingly of non-recyclable fiber, rising apparel discards are exacerbating environmental impacts, overwhelming used clothing outlets, and raising landfill volumes.

Individual consumers can influence clothing industry trends in several ways:

- Limiting clothing purchases.
- Avoiding short-life fashion trends – rejecting this movement altogether or by taking advantage of rent-before-buying programs now offered by a number of retailers.
- Informing others, especially adolescents, of impacts of frequent apparel purchases.
- Checking out used clothing outlets before buying new.
- When buying new, seeking recycled content items, or items containing Tencel®, BCI™, or organic cotton products whenever possible. Also look for Fairtrade Certified or other third-party verified labels regarding labor practices of clothing manufacturers.

[32] Schultz, T. and Suresh (2017)

Sources of Information

Bain, M. 2018. Americans Have Stopped Trying to Stuff More Clothes into their Closets. Quartz, Feb. 26. (https://qz.com/1212305/americans-have-stopped-trying-to-stuff-more-clothes-into-their-closets/)

Batlanki, R. 2017. The Danger of Donating Clothes. Marion West, Oct. 18. (https://merionwest.com/2017/08/18/the-danger-of-donating-clothes/)

Beton, A., Dias, D., Farrant, L., Gibon, T., and Le Guern, Y. 2014. Environmental Improvement Potential of Textiles. JRC Scientific and Technical Reports. Seville: European Commission JRC – IPTS. (http://publications.jrc.ec.europa.eu/repository/bitstream/JRC85895/impro%20textiles_final%20report%20edited_pubsy%20web.pdf)

Chapagain, A., Hoekstra, A., Savenije, H., and Gautam, R. 2006. The Water Footprint of Cotton Consumption: An Assessment of the Impact of Worldwide Consumption of Cotton Products on the Water Resources in the Cotton Producing Countries. Ecological Economics 60(1): 186-203. (https://www.researchgate.net/publication/228377230_The_Water_Footprint_of_Cotton_Consumption)

Chen, H. and Burns, L. 2006. Environmental Analysis of Textile Products. Clothing and Textiles Research Journal 24(3): 248-261. (https://www.researchgate.net/publication/247782661_Environmental_Analysis_of_Textile_Products)

Chitrakorn, K. 2017. Africa vs the USA: A Secondhand Clothing Showdown. Business of Fashion, Oct. 16. (https://www.businessoffashion.com/articles/global-currents/africa-vs-the-usa-a-secondhand-clothing-showdown)

Common Objective. 2018. Volume and Consumption: How Much Does the World Buy? (https://www.commonobjective.co/article/volume-and-consumption-how-much-does-the-world-buy)

Cushman-Roisin, B. and Cremonini, B. 2019. Materials. In: Useful Numbers for Environmental Studies and Meaningful Comparisons, Chapter 1. Dartmouth College, Thayer School of Engineering. (http://www.dartmouth.edu/~cushman/books/Numbers.html)

Garside, M. 2019. Worldwide Production Volume of Chemical and Textile Fibers From 1975 to 2018 (thousand metric tons). (https://www.statista.com/statistics/263154/worldwide-production-volume-of-textile-fibers-since-1975/)

Global Fashion Agenda/Boston Consulting Group. 2017. Pulse of the Fashion Industry 2017, p. 61. (https://globalfashionagenda.com/wp-content/uploads/2017/05/Pulse-of-the-Fashion-Industry_2017.pdf)

International Cotton Advisory Committee. 2018. Did You Know? (https://www.icac.org/LearningCorner/LearningCorner?CategoryId=1&MenuId=14)

Jewell, J. LCA Update of Cotton Fiber and Fabric Life Cycle Inventory. Cotton Incorporated. (http://resource.cottoninc.com/LCA/2016-LCA-Full-Report-Update.pdf)

Kalliala, E. and Nousiainen, P. 1999. Life Cycle Assessment Environmental Profile of Cotton and Polyester-Cotton Fabrics. AUTEX Research Journal 1(1): 8-20. (https://pdfs.semanticscholar.org/80e3/da631dd6d7d86d288275c390e63849fc4498.pdf)

Koh, H. 2017. A Way to Repeatedly Recycle Polyester Has Just Been Discovered. Eco-Business, Oct. 3. (https://www.eco-business.com/news/a-way-to-repeatedly-recycle-polyester-has-just-been-discovered/)

Laitala, K., Grimstad, I. and Henry, B. 2018. Does Use Matter? Comparison of Environmental Impacts of Clothing Based on Fiber Type. Sustainability 2018, 10, 2524. (https://www.mdpi.com/2071-1050/10/7/2524/htm)

Lenzig Group. 2018. Annual Report 2017. (https://www.lenzing.com/index.php?type=88245&tx_filedownloads_file%5bfileName%5d=fileadmin/content/PDF/07_Finanzen/Geschaeftsberichte/EN/GB_2017_EN.pdf)

Mahoney, S. 2019. Macy's, JC Penney, Banana Republic: Will Used Clothes and Subscriptions Help? Marketing Daily, Aug. 18. (https://www.mediapost.com/publications/article/339418/macys-jc-penney-banana-republic-will-used-clot.html)

Miljögiraff. 2016. LCA of Recycling Cotton. Miljögiraff Report 75 (Sweden). (https://www.researchgate.net/publication/319710965_LCA_on_Recycling_Cotton)

Moazzem, S., Daver, F., Crossin, E. and Wang, L. 2018. Assessing Environmental Impact of Textile Supply Chain Using Life Cycle Assessment Methodology. The Journal of the Textile Institute 109(12): 1574-1585. (https://www.tandfonline.com/doi/full/10.1080/00405000.2018.1434113)

PE International. 2014. The Life Cycle Assessment (LCA) of Organic Cotton Fiber – A Global Average. Textile Exchange. (https://textileexchange.org/wp-content/uploads/2017/06/TE-LCA_of_Organic_Cotton-Fiber-Summary_of-Findings.pdf)

Quartr.us. 2018. Polyester Fabric –World War II and the Invention of Polyester. (https://quatr.us/modern-europe/where-did-polyester-come-from.htm)

Rahman, M. and Haque, M. 2016. Investigation of Fabric Wastages in Knit T-Shirt Manufacturing Industry in Bangladesh. Momin 16.10 (1). MS Thesis, Department of Textile Engineering, Daffodil International University. (https://www.researchgate.net/publication/325011931_INVESTIGATION_OF_FABRIC_WASTAGES_IN_KNIT_T-SHIRT_MANUFACTURING_INDUSTRY_IN_BANGLADESH)

Rocha-Munive, M., Soberón, M., Castañeda, S., Niaves, E., Scheinvar, E., Eguiarte, L. E., … Souza, V. 2018. Evaluation of the Impact of Genetically Modified Cotton After 20 Years of Cultivation in Mexico. Frontiers in Bioengineering and Biotechnology, 6, 82. (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6023983/)

Roos, S., Sandin, G., Zamani, B. and Peters, G. 2015. Environmental Assessment of Swedish Fashion Consumption: Five Garments – Sustainable Futures. Mistra Future Fashion. (http://mistrafuturefashion.com/wp-content/uploads/2015/06/Environmental-assessment-of-Swedish-fashion-consumption-LCA.pdf)

Šajn, N. 2019. Environmental Impact of the Textile and Clothing Industry: What Consumers Need to Know. European Parliamentary Research Service. (http://www.europarl.europa.eu/RegData/etudes/BRIE/2019/633143/EPRS_BRI(2019)633143_EN.pdf)

Sandin, G. and Peters, G. 2018. Environmental Impact of Textile Reuse and Recycling – A Review. Journal of Cleaner Production 184(20): 353-365. (https://www.sciencedirect.com/science/article/pii/S0959652618305985)

Schultz, T. and Suresh, A. 2017. Life Cycle Assessment Comparing Ten Sources of Manmade Cellulose Fiber: Executive Summary. SCS Global Services Report. (https://www.scsglobalservices.com/files/resources/scs-stella-lca-executive_summary-100617.pdf)

Shen, L. and Patel, M. 2010. Life Cycle Assessment of Man-Made Cellulose Fibres. Lenzinger Berichte 88(2010): 1-59. (http://seeds4green.net/sites/default/files/LIFE%20CYCLE%20ASSESSMENT%20OF%20MAN-MADE%20CELLULOSE%20FIBRES.pdf)

Shen, L. and Patel, M. 2008. Life Cycle Assessment of Polysaccharide Materials: A Review. Journal of Polymers and the Environment 2008 (16): 154. (https://link.springer.com/article/10.1007/s10924-008-0092-9)

Speranskaya, O., Caterbow, A., Buonsante, V., Adan, H., Mutsaers, M., Karkee, R., Ciu, A., Denwood, D., Gorial, M., Geerts, A., Allers, S., Bles, R. and Malhotra, D. 2018. The Sustainability of Fashion: What Role can Consumers Play? Health and Environment Justice Support International. (https://hej-support.org/wp-content/uploads/2018/06/HEJ_Sustainable-textiles.pdf)

Stanton, T., Johnson, M, Nathanail, P., MacNaughtan, W. and Gomes, R. 2019. Freshwater and Airborne Textile Fibre Populations are Dominated by 'Natural', not Microplastic, Fibres. Science of the Total Environment 666(May): 377-389. (https://www.sciencedirect.com/science/article/pii/S0048969719307764)

Townsend, T. 2019. Natural Fibres and the World Economy July 2019. Discover Natural Fibres Initiative. (https://dnfi.org/coir/natural-fibres-and-the-world-economy-july-2019_18043/)

U.S. Environmental Protection Agency. 2019. Facts and Figures about Materials, Waste and Recycling. Textiles: Material-Specific Data. (https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/textiles-material-specific-data)

Van der Velden, N., Patel, M. and Vogtiänder, J. 2014. LCA Benchmarking Study on Textiles Made of Cotton, Polyester, Nylon, Acryl, or Elastane. The International Journal of Life Cycle Assessment 19(2): 331-356. (https://www.researchgate.net/publication/258220983_LCA_benchmarking_study_on_textiles_made_of_cotton_polyester_nylon_acryl_or_elastane)